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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 63, NUMBER 6

SMITHSONIAN PHYSICAL TABLES

SIXTH REVISED EDITION

PREPARED BY
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AID, SMITHSONIAN ASTROPHYSICAL OBSERVATORY

(PUBLICATION 2269)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1914

ADVERTISEMENT.

In connection with the system of meteorological observations established by the Smithsonian Institution about 1850, a series of meteorological tables was compiled by Dr. Arnold Guyot, at the request of Secretary Henry, and the first edition was published in 1852. Though primarily designed for meteorological observers reporting to the Smithsonian Institution, the tables were so widely used by physicists that it seemed desirable to recast the work entirely. It was decided to publish three sets of tables, each representative of the latest knowledge in its field, and independent of one another, but forming a homogeneous series. The first of the new series, Meteorological Tables, was published in 1893, the second, Geographical Tables, in 1894, and the third, Physical Tables, in 1896. In 1909 yet another volume was added, so that the series now comprises: Smithsonian Meteorological Tables, Smithsonian Geographical Tables, Smithsonian Physical Tables, and Smithsonian Mathematical Tables.

The fourteen years which had elapsed in 1910 since the publication of the first edition of the Physical Tables, prepared by Professor Thomas Gray, had brought such changes in the material upon which the tables must be based that it became necessary to make a radical revision for the 5th revised edition issued in 1910. That revision has been still further continued for the present sixth edition.

CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

June, 1914.

PREFACE TO THE 5TH REVISED EDITION.

The present Smithsonian Physical Tables are the outcome of a radical revision of the set of tables compiled by Professor Thomas Gray in 1896. Recent data and many new tables have been added for which the references to the sources have been made more complete; and several mathematical tables have been added, — some of them especially computed for this work. The inclusion of these mathematical tables seems warranted by the demand for them. In order to preserve a uniform change of argument and to facilitate comparison, many of the numbers given in some tables have been obtained by interpolation in the data actually given in the papers quoted.

Our gratitude is expressed for many suggestions and for help in the improvement of the present edition: to the U. S. Bureau of Standards for the revision of the electrical, magnetic, and metrological tables and other suggestions; to the U. S. Coast and Geodetic Survey for the revision of the magnetic and geodetic tables; to the U. S. Geological Survey for various data; to Mr. Van Orstrand for several of the mathematical tables; to Mr. Wead for the data on the musical scales; to Mr. Sosman for the new physical-chemistry data; to Messrs. Abbot, Becker, Lanza, Rosa, and Wood; to the U. S. Bureau of Forestry and to others. We are also under obligation to the authors and publishers of Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen (1905) and B. O. Peirce's Mathematical Tables for the use of certain tables.

It is hardly possible that any series of tables involving so much transcribing, interpolation, and calculation should be entirely free from errors, and the Smithsonian Institution will be grateful, not only for notice of whatever errors may be found, but also for suggestions as to other changes which may seem advisable for later editions.

F. E. FOWLE.

ASTROPHYSICAL OBSERVATORY
OF THE SMITHSONIAN INSTITUTION,
June, 1910

PREFACE TO THE 6TH REVISED EDITION.

The revision commenced for the fifth edition has been continued; a large proportion of the tables have been rechecked, typographical errors corrected, later data inserted and many new tables are added, including among others a new set of wire tables from advance sheets courteously given by the Bureau of Standards, new mathematical tables computed by Mr. Van Orstrand and those on Röntgen rays and radioactivity. The number of tables has been increased from 335 to over 400. We express our gratitude to the Bureau of Standards, to the Geophysical Laboratory, the Geological Survey, and to those who have helped through suggested improvements, new data, or by calling our attention to errors in the earlier editions.

F. E. FOWLE.

ASTROPHYSICAL OBSERVATORY
OF THE SMITHSONIAN INSTITUTION,
October, 1913.

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INTRODUCTION.

UNITS OF MEASUREMENT AND CONVERSION FORMULÆ.

Units. — The quantitative measure of anything is a number which expresses the ratio of the magnitude of the thing to the magnitude of some other thing of the same kind. In order that the number expressing the measure may be intelligible, the magnitude of the thing used for comparison must be known. This leads to the conventional choice of certain magnitudes as units of measurement, and any other magnitude is then simply expressed by a number which tells how many magnitudes equal to the unit of the same kind of magnitude it contains. For example, the distance between two places may be stated as a certain number of miles or of yards or of feet. In the first case, the mile is assumed as a known distance; in the second, the yard, and in the third, the foot. What is sought for in the statement is to convey an idea of the distance by describing it in terms of distances which are either familiar or easily referred to for comparison. Similarly quantities of matter are referred to as so many tons or pounds or grains and so forth, and intervals of time as a number of hours or minutes or seconds. Generally in ordinary affairs such statements appeal to experience; but, whether this be so or not, the statement must involve some magnitude as a fundamental quantity, and this must be of such a character that, if it is not known, it can be readily referred to. We become familiar with the length of a mile by walking over distances expressed in miles, with the length of a yard or a foot by examining a yard or a foot measure and comparing it with something easily referred to, — say our own height, the length of our foot or step, — and similarly for quantities of other kinds. This leads us to be able to form a mental picture of such magnitudes when the numbers expressing them are stated, and hence to follow intelligently descriptions of the results of scientific work. The possession of copies of the units enables us by proper comparisons to find the magnitude-numbers expressing physical quantities for ourselves. The numbers descriptive of any quantity must depend on the intrinsic magnitude of the unit in terms of which it is described. Thus a mile is 1760 yards, or 5280 feet, and hence when a mile is taken as the unit the magnitude-number for the distance is 1, when a yard is taken as the unit the magnitude-number is 1760, and when a foot is taken it is 5280. Thus, to obtain the magnitude-number for a quantity in terms of a new unit when it is already known in terms of another we have to multiply the old magnitude-number by the ratio of the intrinsic values of the old and new units; that is, by the number of the new units required to make one of the old.

Fundamental Units of Length and Mass. — It is desirable that as few different kinds of unit quantities as possible should be introduced into our measurements, and since it has been found possible and convenient to express a large number of physical quantities in terms of length or mass or time units and combinations of these, they have been very generally adopted as fundamental units. Two systems of such units are used in this country for scientific measurements, namely, the customary, and the French or metric, systems. Tables of conversion factors are given in the book for facilitating comparisons between quantities expressed in terms of one system with similar quantities expressed in the other. In the customary system the standard unit of length is the yard and is now defined as 3600/3937 meter. The unit of mass is the avoirdupois pound and is defined as 1/2.20462 kilogram.

The British yard is defined as the "straight line or distance (at 62° F.) between the transverse lines in the two gold plugs in the bronze bar deposited in the office of the exchequer." The British standard of mass is the pound avoirdupois and is the mass of a piece of platinum marked "P. S. 1844, 1 lb.," preserved in the exchequer office.

In the metric system the standard of length is the meter and is defined as the distance between two lines at 0° Centrigrade on a platinum iridium bar deposited at the International Bureau of Weights and Measures. This bar is known as the International Prototype Meter, and its length was derived from the "mètre des Archives," which was made by Borda. Copies of the International Prototype Meter are possessed by the various governments, and are called "National Prototypes."

Borda, Delambre, Laplace, and others, acting as a committee of the French Academy, recommended that the standard unit of length should be the ten millionth part of the length, from the equator to the pole, of the meridian passing through Paris. In 1795 the French Republic passed a decree making this the legal standard of length, and an arc of the meridian extending from Dunkirk to Barcelona was measured by Delambre and Mechain for the purpose of realizing the standard. From the results of that measurement the meter bar was made by Borda. The meter is not now defined in terms of the meridian length, and hence subsequent measurements of the length of the meridian have not affected the length of the meter.

The metric standard of mass is the kilogram and is defined as the mass of a piece of platinum-iridium deposited at the International Bureau of Weights and Measures. This standard is known as the International Prototype Kilogram. Its mass is equal to that of the older standard, the "kilogramme des Archives," made by Borda and intended to have the same mass as a cubic decimeter of distilled water at the temperature of 4° C. Copies of the International Prototype Kilogram are possessed by the various governments, and as in the case of the meter standards are called National Prototypes.

Comparisons of the French and customary standards are given in tabular form in Table 2; and similarly Table 3, differing slightly, compares the British and French systems. In the metric system the decimal subdivision is used, and thus we have the decimeter, the centimeter, and the millimeter as subdivisions, and the dekameter, hektometer, and kilometer as multiples. The centimeter is most commonly used in scientific work.

Time. — The unit of time in both the systems here referred to is the mean solar second, or the 86,400th part of the mean solar day. The unit of time is thus founded on the average time required for the earth to make one revolution on its axis relatively to the sun as a fixed point of reference.

Derived Units. — Units of quantities depending on powers greater than unity of the fundamental length, mass, and time units, or on combinations of different powers of these units, are called "derived units." Thus, the unit of area and of volume are respectively the area of a square whose side is the unit of length and the volume of a cube whose edge is the unit of length. Suppose that the area of a surface is expressed in terms of the foot as fundamental unit, and we wish to find the area-number when the yard is taken as fundamental unit. The yard is 3 times as long as the foot, and therefore the area of a square whose side is a yard is 3×3 times as great as that whose side is a foot. Thus, the surface will only make one ninth as many units of area when the yard is the unit of length as it will make when the foot is that unit. To transform, then, from the foot as old unit to the yard as new unit, we have to multiply the old area-number by 1/9, or by the ratio of the magnitude of the old to that of the new unit of area. This is the same rule as that given above, but it is usually more convenient to express the transformations in terms of the fundamental units directly. In the above case, since on the method of measurement here adopted an area-number is the product of a length-number by a length-number the ratio of two units is the square of the ratio of the intrinsic values of the two units of length. Hence, if l be the ratio of the magnitude of the old to that of the new unit of length, the ratio of the corresponding units of area is l^2. Similarly the ratio of two units of volume will be l^3, and so on for other quantities.

Dimensional Formulæ. — It is convenient to adopt symbols for the ratios of length units, mass units, and time units, and adhere to their use throughout; and in what follows, the small letters, l, m, t, will be used for these ratios. These letters will always represent simple numbers, but the magnitude of the number will depend on the relative magnitudes of the units the ratios of which they represent. When the values of the numbers represented by l, m, t are known, and the powers of l, m, and t involved in any particular unit are also known, the factor for transformation is at once obtained. Thus, in the above example, the value of l was 1/3 and the power of l involved in the expression for area is l^2; hence, the factor for transforming from square feet to square yards is 1/9. These factors have been called by Prof. James Thomson "change ratios," which seems an appropriate term. The term "conversion factor" is perhaps more generally known, and has been used throughout this book.

Conversion Factor. — In order to determine the symbolic expression for the conversion factor for any physical quantity, it is sufficient to determine the degree to which the quantities length, mass, and time are involved in the quantity. Thus, a velocity is expressed by the ratio of the number representing a length to that representing an interval of time, or L/T, an acceleration by a velocity-number divided by an interval of time-number, or L/T^2, and so on, and the corresponding ratios of units must therefore enter to precisely the same degree. The factors would thus be for the above cases, l/t and l/t^2. Equations of the form above given for velocity and acceleration which show the dimensions of the quantity in terms of the fundamental units are called "dimensional equations." Thus

$$E = ML^2T^{-2}$$

is the dimensional equation for energy, and ML^2T^{-2} is the dimensional formula for energy.

In general, if we have an equation for a physical quantity

$$Q = CL^aM^bT^c,$$

where C is a constant and LMT represents length, mass, and time in terms of one set of units, and we wish to transform to another set of units in terms of which the length, mass, and time are $L_1M_1T_1$, we have to find the value of $\frac{L_1}{L}, \frac{M_1}{M}, \frac{T_1}{T}$, which in accordance with the convention adopted above will be $l\ m\ t$, or the ratios of the magnitudes of the old to those of the new units.

Thus $L_1 = Ll$, $M_1 = Mm$, $T_1 = Tt$, and if Q_1 be the new quantity-number

$$Q_1 = CL_1^aM_1^bT_1^c$$
$$= CL^al^aM^bm^bT^ct^c = Ql^am^bt^c,$$

or the conversion factor is $l^am^bt^c$, a quantity of precisely the same form as the dimension formula $L^aM^bT^c$.

We now proceed to form the dimensional and conversion factor formulæ for the more commonly occurring derived units.

1. **Area.** — The unit of area is the square the side of which is measured by the unit of length. The area of a surface is therefore expressed as

$$S = CL^2,$$

where C is a constant depending on the shape of the boundary of the surface and L a linear dimension. For example, if the surface be square and L be the length of a side C is unity. If the boundary be a circle and L be a diameter $C = \pi/4$, and so on. The dimensional formula is thus L^2, and the conversion factor l^2.

2. **Volume.** — The unit of volume is the volume of a cube the edge of which is measured by the unit of length. The volume of a body is therefore expressed as

$$V = CL^3,$$

where as before C is a constant depending on the shape of the boundary. The dimensional formula is L^3 and the conversion factor l^3.

3. **Density.** — The density of a substance is the quantity of matter in the unit of volume. The dimension formula is therefore M/V or ML^{-3}, and conversion factor ml^{-3}.

Example. — The density of a body is 150 in pounds per cubic foot: required the density in grains per cubic inch.

Here m is the number of grains in a pound $= 7000$, and l is the number of inches in a foot $= 12$; $\therefore ml^{-3} = 7000/12^3 = 4.051$. Hence the density is $150 \times 4.051 = 607.6$ in grains per cubic inch.

Note. — The specific gravity of a body is the ratio of its density to the density of a standard substance. The dimension formula and conversion factor are therefore both unity.

4. **Velocity.** — The velocity of a body at any instant is given by the equation $v = \frac{dL}{dT}$, or velocity is the ratio of a length-number to a time-number. The dimension formula is LT^{-1}, and the conversion factor lt^{-1}.

Example. — A train has a velocity of 60 miles an hour: what is its velocity in feet per second?

Here $l = 5280$ and $t = 3600$; $\therefore lt^{-1} = \frac{5280}{3600} = \frac{44}{30} = 1.467$. Hence the velocity $= 60 \times 1.467 = 88.0$ in feet per second.

5. **Angle.** — An angle is measured by the ratio of the length of an arc to the length of the radius of the arc. The dimension formula and the conversion factor are therefore both unity.

6. **Angular Velocity.** — Angular velocity is the ratio of the magnitude of the angle described in an interval of time to the length of the interval. The dimension formula is therefore T^{-1}, and the conversion factor is t^{-1}.

7. **Linear Acceleration.** — Acceleration is the rate of change of velocity or $a = \frac{dv}{dt}$. The dimension formula is therefore VT^{-1} or LT^{-2}, and the conversion factor is lt^{-2}.

Example. — A body acquires velocity at a uniform rate, and at the end of one minute is moving at the rate of 20 kilometers per hour: what is the acceleration in centimeters per second per second?

Since the velocity gained was 20 kilometers per hour in one minute, the acceleration was 1200 kilometers per hour per hour.

Here $l = 100\,000$ and $t = 3600$; $\therefore lt^{-2} = 100\,000/3600^2 = .00771$, and therefore acceleration $= .00771 \times 1200 = 9.26$ centimeters per second.

8. **Angular Acceleration.** — Angular acceleration is rate of change of angu-

lar velocity. The dimensional formula is thus $\frac{\text{angular velocity}}{\text{T}}$ or T^{-2}, and the conversion factor t^{-2}.

9. **Solid Angle.** — A solid angle is measured by the ratio of the surface of the portion of a sphere enclosed by the conical surface forming the angle to the square of radius of the spherical surface, the centre of the sphere being at the vertex of the cone. The dimensional formula is therefore $\frac{\text{area}}{L^2}$ or 1, and hence the conversion factor is also 1.

10. **Curvature.** — Curvature is measured by the rate of change of direction of the curve with reference to distance measured along the curve as independent variable. The dimension formula is therefore $\frac{\text{angle}}{\text{length}}$ or L^{-1}, and the conversion factor is l^{-1}.

11. **Tortuosity.** — Tortuosity is measured by the rate of rotation of the tangent plane round the tangent to the curve of reference when length along the curve is independent variable. The dimension formula is therefore $\frac{\text{angle}}{\text{length}}$ or L^{-1}, and the conversion factor is l^{-1}.

12. **Specific Curvature of a Surface.** — This was defined by Gauss to be, at any point of the surface, the ratio of the solid angle enclosed by a surface formed by moving a normal to the surface round the periphery of a small area containing the point, to the magnitude of the area. The dimensional formula is therefore $\frac{\text{solid angle}}{\text{surface}}$ or L^{-2}, and the conversion factor is thus l^{-2}.

13. **Momentum.** — This is quantity of motion in the Newtonian sense, and is, at any instant, measured by the product of the mass-number and the velocity-number for the body.

Thus the dimension formula is MV or MLT^{-1}, and the conversion factor mlt^{-1}.

Example. — A mass of 10 pounds is moving with a velocity of 30 feet per second: what is its momentum when the centimeter, the gram, and the second are fundamental units?

Here $m = 453.59$, $l = 30.48$, and $t = 1$; $\therefore mlt^{-1} = 453.59 \times 30.48 = 13825$. The momentum is thus $13825 \times 10 \times 30 = 4\,147\,500$.

14. **Moment of Momentum.** — The moment of momentum of a body with reference to a point is the product of its momentum-number and the number expressing the distance of its line of motion from the point. The dimensional formula is thus ML^2T^{-1}, and hence the conversion factor is ml^2t^{-1}.

15. **Moment of Inertia.** — The moment of inertia of a body round any axis is expressed by the formula Σmr^2, where m is the mass of any particle of the body

and r its distance from the axis. The dimension formula for the sum is clearly the same as for each element, and hence is ML^2. The conversion factor is therefore ml^2.

16. **Angular Momentum.** — The angular momentum of a body round any axis is the product of the numbers expressing the moment of inertia and the angular velocity of the body. The dimensional formula and the conversion factor are therefore the same as for moment of momentum given above.

17. **Force.** — A force is measured by the rate of change of momentum it is capable of producing. The dimension formulæ for force and "time rate of change of momentum" are therefore the same, and are expressed by the ratio of momentum-number to time-number or MLT^{-2}. The conversion factor is thus mlt^{-2}.

NOTE. — When mass is expressed in pounds, length in feet, and time in seconds, the unit force is called the poundal. When grams, centimeters, and seconds are the corresponding units the unit of force is called the dyne.

Example. Find the number of dynes in 25 poundals.

Here $m = 453.59$, $l = 30.48$, and $t = 1$; $\therefore mlt^{-2} = 453.59 \times 30.48 = 13825$ nearly. The number of dynes is thus $13825 \times 25 = 345625$ approximately.

18. **Moment of a Couple, Torque, or Twisting Motive.** — These are different names for a quantity which can be expressed as the product of two numbers representing a force and a length. The dimension formula is therefore FL or ML^2T^{-2}, and the conversion factor is ml^2t^{-2}.

19. **Intensity of a Stress.** — The intensity of a stress is the ratio of the number expressing the total stress to the number expressing the area over which the stress is distributed. The dimensional formula is thus FL^{-2} or $ML^{-1}T^{-2}$, and the conversion factor is $ml^{-1}t^{-2}$.

20. **Intensity of Attraction, or "Force at a Point."** — This is the force of attraction per unit mass on a body placed at the point, and the dimensional formula is therefore FM^{-1} or LT^{-2}, the same as acceleration. The conversion factors for acceleration therefore apply.

21. **Absolute Force of a Centre of Attraction, or "Strength of a Centre."** — This is the intensity of force at unit distance from the centre, and is therefore the force per unit mass at any point multiplied by the square of the distance from the centre. The dimensional formula thus becomes FL^2M^{-1} or L^3T^{-2}. The conversion factor is therefore l^3t^{-2}.

22. **Modulus of Elasticity.** — A modulus of elasticity is the ratio of stress intensity to percentage strain. The dimension of percentage strain is a length divided by a length, and is therefore unity. Hence, the dimensional formula of a modulus of elasticity is the same as that of stress intensity, or $ML^{-1}T^{-2}$, and the conversion factor is thus also $ml^{-1}t^{-2}$.

23. **Work and Energy.** — When the point of application of a force, acting on a body, moves in the direction of the force, work is done by the force, and the amount is measured by the product of the force and displacement numbers. The dimensional formula is therefore FL or ML^2T^{-2}.

The work done by the force either produces a change in the velocity of the body or a change of shape or configuration of the body, or both. In the first case it produces a change of kinetic energy, in the second a change of potential energy. The dimension formulæ of energy and work, representing quantities of the same kind, are identical, and the conversion factor for both is ml^2t^{-2}.

24. **Resilience.** — This is the work done per unit volume of a body in distorting it to the elastic limit or in producing rupture. The dimension formula is therefore $ML^2T^{-2}L^{-3}$ or $ML^{-1}T^{-2}$, and the conversion factor $ml^{-1}t^{-2}$.

25. **Power, or Activity.** — Power — or, as it is now very commonly called, activity — is defined as the time rate of doing work, or if W represent work and P power $P = \frac{dw}{dt}$. The dimensional formula is therefore WT^{-1} or ML^2T^{-3}, and the conversion factor ml^2t^{-3}, or for problems in gravitation units more conveniently flt^{-1}, where f stands for the force factor.

Examples. (*a*) Find the number of gram centimeters in one foot pound.

Here the units of force are the attraction of the earth on the pound * and the gram of matter, and the conversion factor is fl, where f is 453.59 and l is 30.48.

Hence the number is $453.59 \times 30.48 = 13825$.

(*b*) Find the number of foot poundals in 1 000 000 centimeter dynes.

Here $m = 1/453.59$, $l = 1/30.48$, and $t = 1$; $\therefore\ ml^2t^{-2} = 1/453.59 \times 30.48^2$, and $10^6ml^2t^{-2} = 10^6/453.59 \times 30.48^2 = 2.373$.

(*c*) If gravity produces an acceleration of 32.2 feet per second per second, how many watts are required to make one horse-power?

One horse-power is 550 foot pounds per second, or $550 \times 32.2 = 17710$ foot poundals per second. One watt is 10^7 ergs per second, that is, 10^7 dyne centimeters per second. The conversion factor is ml^2t^{-3}, where $m = 453.59$, $l = 30.48$, and $t = 1$, and the result has to be divided by 10^7, the number of dyne centimeters per second in the watt.

Hence, $17710\,ml^2t^{-3}/10^7 = 17710 \times 453.59 \times 30.48^2/10^7 = 746.3$.

(*d*) How many gram centimeters per second correspond to 33000 foot pounds per minute?

The conversion factor suitable for this case is flt^{-1}, where f is 453.59, l is 30.48, and t is 60.

Hence, $33000\,lt^{-1} = 33000 \times 453.59 \times 30.48/60 = 7\,604\,000$ nearly.

* It is important to remember that in problems like that here given the term "pound" or "gram" refers to force and not to mass.

HEAT UNITS.

1. If heat be measured in dynamical units its dimensions are the same as those of energy, namely ML^2T^{-2}. The most common measurements, however, are made in thermal units, that is, in terms of the amount of heat required to raise the temperature of unit mass of water one degree of temperature at some stated temperature. This method of measurement involves the unit of mass and some unit of temperature ; and hence, if we denote temperature-numbers by Θ and their conversion factors by θ, the dimensional formula and conversion factor for quantity of heat will be $M\Theta$ and $m\theta$ respectively. The relative amount of heat compared with water as standard substance required to raise unit mass of different substances one degree in temperature is called their specific heat, and is a simple number.

Unit volume is sometimes used instead of unit mass in the measurement of heat, the units being then called thermometric units. The dimensional formula is in that case changed by the substitution of volume for mass, and becomes $L^3\Theta$, and hence the conversion factor is to be calculated from the formula $l^3\theta$.

For other physical quantities involving heat we have:—

2. **Coefficient of Expansion.**—The coefficient of expansion of a substance is equal to the ratio of the change of length per unit length (linear), or change of volume per unit volume (voluminal) to the change of temperature. These ratios are simple numbers, and the change of temperature is inversely as the magnitude of the unit of temperature. Hence the dimensional and conversion-factor formulæ are Θ^{-1} and θ^{-1}.

3. **Conductivity, or Specific Conductance.**—This is the quantity of heat transmitted per unit of time per unit of surface per unit of temperature gradient. The equation for conductivity is therefore, with H as quantity of heat,

$$K = \frac{H}{\frac{\Theta}{L} L^2 T}$$

and the dimensional formula $\frac{H}{\Theta LT} = \frac{M}{LT}$, which gives $ml^{-1}t^{-1}$ for conversion factor.

In thermometric units the formula becomes L^2T^{-1}, which properly represents diffusivity. In dynamical units H becomes ML^2T^{-2}, and the formula changes to $MLT^{-3}\Theta^{-1}$. The conversion factors obtained from these are l^2t^{-1} and $mlt^{-3}\theta^{-1}$ respectively.

4. **Thermal Capacity.** — This is the product of the number for mass and the specific heat, and hence the dimensional formula and conversion factor are simply M and m.

5. **Latent Heat.** — Latent heat is the ratio of the number representing the quantity of heat required to change the state of a body to the number representing the quantity of matter in the body. The dimensional formula is therefore $M\Theta/M$ or Θ, and hence the conversion factor is simply the ratio of the temperature units or θ. In dynamical units the factor is l^2t^{-2}.*

6. **Joule's Equivalent.** — Joule's dynamical equivalent is connected with quantity of heat by the equation

$$ML^2T^{-2} = JH \text{ or } JM\Theta.$$

This gives for the dimensional formula of J the expression $L^2T^{-2}\Theta^{-1}$. The conversion factor is thus represented by $l^2t^{-2}\theta^{-1}$. When heat is measured in dynamical units J is a simple number.

7. **Entropy.** — The entropy of a body is directly proportional to the quantity of heat it contains and inversely proportional to its temperature. The dimensional formula is thus $M\Theta/\Theta$ or M, and the conversion factor is m. When heat is measured in dynamical units the factor is $ml^2t^{-2}\theta^{-1}$.

Examples. (*a*) Find the relation between the British thermal unit, the calorie, and the therm.

Neglecting the variation of the specific heat of water with temperature, or defining all the units for the same temperature of the standard substance, we have the following definitions. The *British thermal unit* is the quantity of heat required to raise the temperature of one pound of water 1° F. The *calorie* is the quantity of heat required to raise the temperature of one kilogramme of water 1° C. The *therm* is the quantity of heat required to raise the temperature of one gramme of water 1° C. Hence: —

(1) To find the number of calories in one British thermal unit, we have $m = .45359$ and $\theta = \frac{5}{9}$; $\therefore m\theta = .45359 \times 5/9 = .25199$.

(2) To find the number of therms in one calorie, $m = 1000$ and $\theta = 1$; $\therefore m\theta = 1000$.

It follows at once that the number of therms in one British thermal unit is $1000 \times .25199 = 251.99$.

(*b*) What is the relation between the foot grain second Fahrenheit-degree and the centimetre gramme second Centigrade-degree units of conductivity?

The number of the latter units in one of the former is given by the for-

* It will be noticed that when Θ is given the dimension formula L^2T^{-2} the formulæ in thermal and dynamical units are always identical. The thermometric units practically suppress mass.

mula $ml^{-1}t^{-1}\theta^{\circ}$, where $m = .064799$, $l = 30.48$, and $t = 1$, and is therefore $=$ $.064799/30.48 = 2.126 \times 10^{-3}$.

(*c*) Find the relation between the units stated in (*b*) for emissivity.

In this case the conversion formula is $ml^{-2}t^{-1}$, where ml and t have the same value as before. Hence the number of the latter units in the former is $0.064799/30.48^2 = 6.975 \times 10^{-5}$.

(*d*) Find the number of centimeter gram second units in the inch grain hour unit of emissivity.

Here the formula is $ml^{-2}t^{-1}$, where $m = 0.064799$, $l = 2.54$, and $t = 3600$. Therefore the required number is $0.064799/2.54^2 \times 3600 = 2.790 \times 10^{-6}$.

(*e*) If Joule's equivalent be 776 foot pounds per pound of water per degree Fahrenheit, what will be its value in gravitation units when the metre, the kilogramme, and the degree Centigrade are units?

The conversion factor in this case is $\frac{l^2t^{-2}\theta^{-1}}{lt^{-2}}$ or $l\theta^{-1}$, where $l = .3048$ and $\theta^{-1} = 1.8$; $\therefore$ $776 \times .3048 \times 1.8 = 425.7$.

(*f*) If Joule's equivalent be 24832 foot poundals when the degree Fahrenheit is unit of temperature, what will be its value when kilogram meter second and degree-Centigrade units are used?

The conversion factor is $l^2t^{-2}\theta^{-1}$, where $l = .3048$, $t = 1$, and $\theta^{-1} = 1.8$; $\therefore$ $24832 \times l^2t^{-2}\theta^{-1} = 24832 \times .3048^2 \times 1.8 = 4152.5$.

In gravitation units this would give $4152.5/9.81 = 423.3$.

ELECTRIC AND MAGNETIC UNITS.

There are two systems of these units, the electrostatic and the electromagnetic systems, which differ from each other because of the different fundamental suppositions on which they are based. In the electrostatic system the repulsive force between two quantities of static electricity is made the basis. This connects force, quantity of electricity, and length by the equation $f = a\frac{qq_1}{l^2}$, where f is force, a a quantity depending on the units employed and on the nature of the medium, q and q_1 quantities of electricity, and l the distance between q and q_1. The magnitude of the force f for any particular values of q, q_1 and l depends on a property of the medium across which the force takes place called its inductive capacity. The inductive capacity of air has generally been assumed as unity, and the inductive capacity of other media expressed as a number representing the ratio of the inductive capacity of the medium to that of air. These numbers are known as the specific inductive capacities of the media. According to the ordinary assumption, then, of air as the standard medium, we obtain unit quantity of electricity when in the above equation $q = q_1$, and f, a, and l are each unity. A formal definition is given below.

In the electromagnetic system the repulsion between two magnetic poles or quantities of magnetism is taken as the basis. In this system the quantities force, quantity of magnetism, and length are connected by an equation of the form

$$f = a\frac{mm_{\prime}}{l^2},$$

where m and $m_{\prime}$ are in this case quantities of magnetism, and the other symbols have the same meaning as before. In this case it has been usual to assume the magnetic inductive capacity of air to be unity, and to express the magnetic inductive capacity of other media as a simple number representing the ratio of the inductive capacity of the medium to that of air. These numbers, by analogy with specific inductive capacity for electricity, might be called specific inductive capacities for magnetism. They are usually called permeabilities. (*Vide* Thomson, "Papers on Electrostatics and Magnetism," p. 484.) In this case, also, like that for electricity, the unit quantity of magnetism is obtained by making $m = m_{\prime}$, and f, a, and l each unity.

In both these cases the intrinsic inductive capacity of the standard medium is suppressed, and hence also that of all other media. Whether this be done or not, direct experiment has to be resorted to for the determination of the absolute values of the units and the relations of the units in the one system to those in the other. The character of this relation can be directly inferred from the dimensional formulæ of the different quantities, but these can give no information as to the relative absolute values of the units in the two systems. Prof. Rücker has suggested (Phil. Mag. vol. 27) the advisability of at least indicating the existence of the suppressed properties by putting symbols for them in the dimensional formulæ. This has the advantage of showing how the magnitudes of the different units would be affected by a change in the standard medium, or by making the standard medium different for the two systems. In accordance with this idea, the symbols K and P have been introduced into the formulæ given below to represent inductive capacity in the electrostatic and the electromagnetic systems respectively. In the conversion formulæ k and p are the ordinary specific inductive capacities and permeabilities of the media when air is taken as the standard, or generally those with reference to the first medium taken as standard. The ordinary formulæ may be obtained by putting K and P equal to unity.

ELECTROSTATIC UNITS.

1. **Quantity of Electricity.** — The unit quantity of electricity is defined as that quantity which if concentrated at a point and placed at unit distance from an equal and similarly concentrated quantity repels it, or is repelled by it, with unit force. The medium or dielectric is usually taken as air, and the other units in accordance with the centimeter gram second system.

In this case we have the force of repulsion proportional directly to the square of the quantity of electricity and inversely to the square of the distance between the quantities and to the inductive capacity. The dimensional formula is therefore the same as that for $[\text{force} \times \text{length}^2 \times \text{inductive capacity}]^{\frac{1}{2}}$ or $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}$, and the conversion factor is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}k^{\frac{1}{2}}$.

2. **Electric Surface Density and Electric Displacement.** — The density of an electric distribution at any point on a surface is measured by the quantity per unit of area, and the electric displacement at any point in a dielectric is measured by the quantity displaced per unit of area. These quantities have therefore the same dimensional formula, namely, the ratio of the formulæ for quantity of electricity and for area or $M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}K^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}k^{\frac{1}{2}}$.

3. **Electric Force at a Point, or Intensity of Electric Field.** — This is measured by the ratio of the magnitude of the force on a quantity of electricity at a point to the magnitude of the quantity of electricity. The dimensional formula is therefore the ratio of the formulæ for force and electric quantity, or

$$\frac{MLT^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}K^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$.

4. **Electric Potential and Electromotive Force.** — Change of potential is proportional to the work done per unit of electricity in producing the change. The dimensional formula is therefore the ratio of the formulæ for work and electric quantity, or

$$\frac{ML^2T^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$.

5. **Capacity of a Conductor.** — The capacity of an insulated conductor is proportional to the ratio of the numbers representing the quantity of electricity in a charge and the potential of the charge. The dimensional formula is thus the ratio of the two formulæ for electric quantity and potential, or

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}} = LK,$$

which gives lk for conversion factor. When K is taken as unity, as in the ordinary units, the capacity of an insulated conductor is simply a length.

6. **Specific Inductive Capacity.** — This is the ratio of the inductive capacity of the substance to that of a standard substance, and hence the dimensional formula is K/K or 1.*

7. **Electric Current.** — Current is quantity flowing past a point per unit of time. The dimensional formula is thus the ratio of the formulæ for electric quantity and for time, or

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}}{T} = M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}K^{\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-2}k^{\frac{1}{2}}$.

* According to the ordinary definition referred to air as standard medium, the specific inductive capacity of a substance is K, or is identical in dimensions with what is here taken as inductive capacity. Hence in that case the conversion factor must be taken as 1 on the electrostatic and as $l^{-2}t^2$ on the electromagnetic system.

8. **Conductivity, or Specific * Conductance.** — This, like the corresponding term for heat, is quantity per unit area per unit potential gradient per unit of time. The dimensional formula is therefore

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}K^{\frac{1}{2}}}{L^2\dfrac{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}}{L}T} = T^{-1}K, \text{ or } \frac{\text{electric quantity}}{\text{area} \times \text{potential gradient} \times \text{time}}.$$

The conversion factor is $t^{-1}k$.

9. **Specific * Resistance.** — This is the reciprocal of conductivity as above defined, and hence the dimensional formula and conversion factor are respectively TK^{-1} and tk^{-1}.

10. **Conductance.** — The conductance of any part of an electric circuit, not containing a source of electromotive force, is the ratio of the numbers representing the current flowing through it and the difference of potential between its ends. The dimensional formula is thus the ratio of the formulæ for current and potential, or

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}K^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}K^{-\frac{1}{2}}} = LT^{-1}K,$$

from which we get the conversion factor $lt^{-1}k$.

11. **Resistance.**—This is the reciprocal of conductance, and therefore the dimensional formula and the conversion factor are respectively $L^{-1}TK^{-1}$ and $l^{-1}tk^{-1}$.

EXAMPLES OF CONVERSION IN ELECTROSTATIC UNITS.

(*a*) Find the factor for converting quantity of electricity expressed in foot grain second units to the same expressed in c. g. s. units.

By (1) the formula is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}k^{\frac{1}{2}}$, in which in this case $m = 0.0648$, $l = 30.48$, $t = 1$, and $k = 1$; ∴ the factor is $0.0648^{\frac{1}{2}} \times 30.48^{\frac{3}{2}} = 4.2836$.

(*b*) Find the factor required to convert electric potential from millimeter milligram second units to c. g. s. units.

By (4) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}k^{-\frac{1}{2}}$, and in this case $m = 0.001$, $l = 0.1$, $t = 1$, and $k = 1$; ∴ the factor $= 0.001^{\frac{1}{2}} \times 0.1^{\frac{1}{2}} = 0.01$.

(*c*) Find the factor required to convert from foot grain second and specific inductive capacity 6 units to c. g. s. units.

By (5) the formula is lk, and in this case $l = 30.48$ and $k = 6$; ∴ the factor $= 30.48 \times 6 = 182.88$.

* The term "specific," as used here and in 9, refers conductance and resistance to that between the ends of a bar of unit section and unit length, and hence is different from the same term in specific heat, specific inductivity, capacity, etc., which refer to a standard substance.

ELECTROMAGNETIC UNITS.

As stated above, these units bear the same relation to unit quantity of magnetism that the electric units do to quantity of electricity. Thus, when inductive capacity is suppressed, the dimensional formula for magnetic quantity on this system is the same as that for electric quantity on the electrostatic system. All quantities in this system which only differ from corresponding quantities defined above by the substitution of magnetic for electric quantity may have their dimensional formulæ derived from those of the corresponding quantity by substituting P for K.

1. **Magnetic Pole, or Quantity of Magnetism.** — Two unit quantities of magnetism concentrated at points unit distance apart repel each other with unit force. The dimensional formula is thus the same as for [force $\times$ length^2 $\times$ inductive capacity]$^{\frac{1}{2}}$ or $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}p^{\frac{1}{2}}$.

2. **Density of Surface Distribution of Magnetism.** — This is measured by quantity of magnetism per unit area, and the dimension formula is therefore the ratio of the expressions for magnetic quantity and for area, or $M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{\frac{1}{2}}$, which gives the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

3. **Magnetic Force at a Point, or Intensity of Magnetic Field.** — The number for this is the ratio of the numbers representing the magnitudes of the force on a magnetic pole placed at the point and the magnitude of the magnetic pole.

The dimensional formula is therefore the ratio of the expressions for force and magnetic quantity, or

$$\frac{MLT^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{-\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

4. **Magnetic Potential.** — The magnetic potential at a point is measured by the work which is required to bring unit quantity of positive magnetism from zero potential to the point. The dimensional formula is thus the ratio of the formula for work and magnetic quantity, or

$$\frac{ML^2T^{-2}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}},$$

which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

5. **Magnetic Moment.** — This is the product of the numbers for pole strength and length of a magnet. The dimensional formula is therefore the product of the formulæ for magnetic quantity and length, or $M^{\frac{1}{2}}L^{\frac{5}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{5}{2}}t^{-1}p^{\frac{1}{2}}$.

6. **Intensity of Magnetization.** — The intensity of magnetization of any portion of a magnetized body is the ratio of the numbers representing the magni-

tude of the magnetic moment of that portion and its volume. The dimensional formula is therefore the ratio of the formulæ for magnetic moment and volume, or

$$\frac{M^{\frac{1}{2}}L^{\frac{5}{2}}T^{-1}P^{\frac{1}{2}}}{L^{3}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{\frac{1}{2}}.$$

The conversion factor is therefore $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

7. **Magnetic Permeability,* or Specific Magnetic Inductive Capacity.** — This is the analogue in magnetism to specific inductive capacity in electricity. It is the ratio of the magnetic induction in the substance to the magnetic induction in the field which produces the magnetization, and therefore its dimensional formula and conversion factor are unity.

8. **Magnetic Susceptibility.** — This is the ratio of the numbers which represent the values of the intensity of magnetization produced and the intensity of the magnetic field producing it. The dimensional formula is therefore the ratio of the formulæ for intensity of magnetization and magnetic field or

$$\frac{M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{-\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}} \text{ or } P.$$

The conversion factor is therefore p, and both the dimensional formula and conversion factor are unity in the ordinary system.

9. **Current Strength.** — A current of strength c flowing round a circle of radius r produces a magnetic field at the centre of intensity $2\pi c/r$. The dimensional formula is therefore the product of the formulæ for magnetic field intensity and length, or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}$, which gives the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$.

10. **Current Density, or Strength of Current at a Point.** — This is the ratio of the numbers for current strength and area. The dimensional formula and the conversion factor are therefore $M^{\frac{1}{2}}L^{-\frac{3}{2}}T^{-1}P^{-\frac{1}{2}}$ and $m^{\frac{1}{2}}l^{-\frac{3}{2}}t^{-1}p^{-\frac{1}{2}}$.

11. **Quantity of Electricity.** — This is the product of the numbers for current and time. The dimensional formula is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}} \times T = M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}p^{-\frac{1}{2}}$.

12. **Electric Potential, or Electromotive Force.** — As in the electrostatic system, this is the ratio of the numbers for work and quantity of electricity. The dimensional formula is therefore

$$\frac{ML^{2}T^{-2}}{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}} = M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}},$$

and the conversion factor $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-2}p^{\frac{1}{2}}$.

* Permeability, as ordinarily taken with the standard medium as unity, has the same dimension formula and conversion factor as that which is here taken as magnetic inductive capacity. Hence for ordinary transformations the conversion factor should be taken as 1 in the electromagnetic and $l^{-2}t^{2}$ in the electrostatic systems.

13. **Electrostatic Capacity.** — This is the ratio of the numbers for quantity of electricity and difference of potential. The dimensional formula is therefore

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}}}=L^{-1}T^{2}P^{-1},$$

and the conversion factor $l^{-1}t^{2}p^{-1}$.

14. **Resistance of a Conductor.** — The resistance of a conductor or electrode is the ratio of the numbers for difference of potential between its ends and the constant current it is capable of producing. The dimensional formula is therefore the ratio of those for potential and current or

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}}=LT^{-1}P.$$

The conversion factor thus becomes $lt^{-1}p$, and in the ordinary system resistance has the same conversion factor as velocity.

15. **Conductance.** — This is the reciprocal of resistance, and hence the dimensional formula and conversion factor are respectively $L^{-1}TP^{-1}$ and $l^{-1}tp^{-1}$.

16. **Conductivity, or Specific Conductance.** — This is quantity of electricity transmitted per unit of area per unit of potential gradient per unit of time. The dimensional formula is therefore derived from those of the quantities mentioned as follows: —

$$\frac{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}}{L^{2}\dfrac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}}}{L}T}=L^{-2}TP^{-1}.$$

The conversion factor is therefore $l^{-2}tp^{-1}$.

17. **Specific Resistance.** — This is the reciprocal of conductivity as defined in 16, and hence the dimensional formula and conversion factor are respectively $L^{2}T^{-1}P$ and $l^{2}t^{-1}p$.

18. **Coefficient of Self-Induction, or Inductance, or Electro-kinetic Inertia.** — These are for any circuit the electromotive force produced in it by unit rate of variation of the current through it. The dimensional formula is therefore the product of the formulæ for electromotive force and time divided by that for current or

$$\frac{M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}}}{M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}}}\times T=LP.$$

The conversion factor is therefore lp, and in the ordinary system is the same as that for length.

19. **Coefficient of Mutual Induction.** — The mutual induction of two circuits is the electromotive force produced in one per unit rate of variation of the current in the other. The dimensional formula and the conversion factor are therefore the same as those for self-induction.

20. **Electro-kinetic Momentum.** — The number for this is the product of the numbers for current and for electro-kinetic inertia. The dimensional formula is therefore the product of the formulæ for these quantities, or $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{-\frac{1}{2}} \times LP = M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-1}p^{\frac{1}{2}}$.

21. **Electromotive Force at a Point.** — The number for this quantity is the ratio of the numbers for electric potential or electromotive force as given in 12, and for length. The dimensional formula is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-2}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-2}p^{\frac{1}{2}}$.

22. **Vector Potential.** — This is time integral of electromotive force at a point, or the electro-kinetic momentum at a point. The dimensional formula may therefore be derived from 21 by multiplying by T, or from 20 by dividing by L. It is therefore $M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}P^{\frac{1}{2}}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$.

23. **Thermoelectric Height.** — This is measured by the ratio of the numbers for electromotive force and for temperature. The dimensional formula is therefore the ratio of the formulæ for these two quantities, or $M^{\frac{1}{2}}L^{\frac{3}{2}}T^{-2}P^{\frac{1}{2}}\Theta^{-1}$, and the conversion factor $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-2}p^{\frac{1}{2}}\theta^{-1}$.

24. **Specific Heat of Electricity.** — This quantity is measured in the same way as 23, and hence has the same formulæ.

25. **Coefficient of Peltier Effect.** — This is measured by the ratio of the numbers for quantity of heat and for quantity of electricity. The dimensional formula is therefore

$$\frac{M\Theta}{M^{\frac{1}{2}}L^{\frac{1}{2}}P^{-\frac{1}{2}}} = M^{\frac{1}{2}}L^{-\frac{1}{2}}P^{\frac{1}{2}}\Theta,$$

and the conversion factor $m^{\frac{1}{2}}l^{-\frac{1}{2}}p^{\frac{1}{2}}\theta$.

EXAMPLES OF CONVERSION IN ELECTROMAGNETIC UNITS.

(*a*) Find the factor required to convert intensity of magnetic field from foot grain minute units to c. g. s. units.

By (3) the formula is $m^{\frac{1}{2}}l^{-\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$, and in this case $m = 0.0648$, $l = 30.48$, $t = 60$, and $p = 1$; $\therefore$ the factors $= 0.0648^{\frac{1}{2}} \times 30.48^{-\frac{1}{2}} \times 60^{-1} = 0.000076847$.

Similarly to convert from foot grain second units to c. g. s. units the factor is $0.0648^{\frac{1}{2}} \times 30.48^{-\frac{1}{2}} = 0.046108$.

(*b*) How many c. g. s. units of magnetic moment make one foot grain second unit of the same quantity?

By (5) the formula is $m^{\frac{1}{2}}l^{\frac{5}{2}}t^{-1}p^{\frac{1}{2}}$, and the values for this problem are $m = 0.0648$, $l = 30.48$, $t = 1$, and $p = 1$; $\therefore$ the number $= 0.0648^{\frac{1}{2}} \times 30.48^{\frac{5}{2}} = 1305.6$.

(*c*) If the intensity of magnetization of a steel bar be 700 in c. g. s. units, what will it be in millimeter milligram second units?

By (6) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{\frac{1}{2}}$, and in this case $m = 1000$, $l = 10$, $t = 1$, and $p = 1$; ∴ the intensity $= 700 \times 1000^{\frac{1}{2}} \times 10^{\frac{1}{2}} = 70000$.

(*d*) Find the factor required to convert current strength from c. g. s. units to earth quadrant 10^{-11} gram and second units.

By (9) the formula is $m^{\frac{1}{2}}l^{\frac{1}{2}}t^{-1}p^{-\frac{1}{2}}$, and the values of these quantities are here $m = 10^{11}$, $l = 10^{-9}$, $t = 1$, and $p = 1$; ∴ the factor $= 10^{\frac{11}{2}} \times 10^{-\frac{9}{2}} = 10$.

(*e*) Find the factor required to convert resistance expressed in c. g. s. units into the same expressed in earth-quadrant 10^{-11} gram and second units.

By (14) the formula is $lt^{-1}p$, and for this case $l = 10^{-9}$, $t = 1$, and $p = 1$; ∴ the factor $= 10^{-9}$.

(*f*) Find the factor required to convert electromotive force from earth-quadrant 10^{-11} gram and second units to c. g. s. units.

By (12) the formula is $m^{\frac{1}{2}}l^{\frac{3}{2}}t^{-2}p^{\frac{1}{2}}$, and for this case $m = 10^{-11}$, $l = 10^{9}$, $t = 1$, and $p = 1$; ∴ the factor $= 10^{8}$.

PRACTICAL UNITS.

In practical electrical measurements the units adopted are either multiples or submultiples of the units founded on the centimeter, the gram, and the second as fundamental units, and air is taken as the standard medium, for which K and P are assumed unity. The following, quoted from the report to the Honorable the Secretary of State, under date of November 6th, 1893, by the delegates representing the United States, gives the ordinary units with their names and values as defined by the International Congress at Chicago in 1893:—

"*Resolved*, That the several governments represented by the delegates of this International Congress of Electricians be, and they are hereby, recommended to formally adopt as legal units of electrical measure the following: As a unit of resistance, the *international ohm*, which is based upon the ohm equal to 10^9 units of resistance of the C. G. S. system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 grams in mass, of a constant cross-sectional area and of the length of 106.3 centimeters.

"As a unit of current, the *international ampère*, which is one tenth of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications,* deposits silver at the rate of 0.001118 of a gram per second.

* "In the following specification the term 'silver voltameter' means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time average of the current, or, if the current has been kept constant, the current itself can be deduced.

"In employing the silver voltameter to measure currents of about one ampère, the following arrangements should be adopted:—

"As a unit of electromotive force, the *international volt*, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampère, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the accompanying specification.*

"As a unit of quantity, the *international coulomb*, which is the quantity of electricity transferred by a current of one international ampère in one second.

"As a unit of capacity, the *international farad*, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.†

"As a unit of work, the *joule*, which is equal to 10^7 units of work in the c. g. s. system, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampère in an international ohm.

"As a unit of power, the *watt*, which is equal to 10^7 units of power in the c. g. s. system, and which is represented sufficiently well for practical use by the work done at the rate of one joule per second.

"As the unit of induction, the *henry*, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampère per second.

"The Chamber also voted that it was not wise to adopt or recommend a standard of light at the present time."

By an Act of Congress approved July 12th, 1894, the units recommended by the Chicago Congress were adopted in this country with only some unimportant verbal changes in the definitions.

By an Order in Council of date August 23d, 1894, the British Board of Trade adopted the ohm, the ampere, and the volt, substantially as recommended by the Chicago Congress. The other units were not legalized in Great Britain. They are, however, in general use in that country and all over the world.

"The kathode on which the silver is to be deposited should take the form of a platinum bowl not less than 10 centimeters in diameter and from 4 to 5 centimeters in depth.

"The anode should be a plate of pure silver some 30 square centimeters in area and 2 or 3 millimeters in thickness.

"This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the anode from falling on to the kathode, the anode should be wrapped round with pure filter paper, secured at the back with sealing wax.

"The liquid should consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

"The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms."

* A committee, consisting of Messrs. Helmholtz, Ayrton, and Carhart, was appointed to prepare specifications for the Clark's cell, but no report was made, on account of Helmholtz's death.

† The one millionth part of the farad is more commonly used in practical measurements, and is called the microfarad.

PHYSICAL TABLES

TABLE 1.

FUNDAMENTAL AND DERIVED UNITS.

To change a quantity from one system of units to another: substitute in the corresponding conversion factor from the following table the ratio of the magnitudes of the *old* units to the *new* and multiply the old quantity by the resulting number. For example: to reduce velocity in miles per hour to feet per second, the conversion factor is $l t^{-1}$; $l=5280/1$, $t=3600/1$, therefore the factor$=5280/3600=1.467$.

(*a*) FUNDAMENTAL UNITS.

Name of Unit.	Symbol.	Conversion Factor.
Length.	L	l
Mass.	M	m
Time.	T	t
Temperature.	Θ	θ
Electric Inductive Capacity.	K	k
Magnetic Inductive Capacity.	P	p

(*b*) DERIVED UNITS.

I. Geometric and Dynamic Units.

Name of Unit.	Conversion Factor.
Area.	l^2
Volume.	l^3
Angle.	1
Solid Angle.	1
Curvature.	l^{-1}
Tortuosity.	l^{-1}
Specific curvature of a surface.	l^{-2}
Angular velocity.	t^{-1}
Angular acceleration.	t^{-2}
Linear velocity.	$l t^{-1}$
Linear acceleration.	$l t^{-2}$
Density.	$m l^{-3}$
Moment of inertia.	$m l^2$
Intensity of attraction, or "force at a point."	$l t^{-2}$
Absolute force of a centre of attraction, or "strength of a centre."	$l^3 t^{-2}$
Momentum.	$m l t^{-1}$
Moment of momentum, or angular momentum.	$m l^2 t^{-1}$
Force.	$m l t^{-2}$
Moment of a couple, or torque.	$m l^2 t^{-2}$
Intensity of stress.	$m l^{-1} t^{-2}$
Modulus of elasticity.	$m l^{-1} t^{-2}$
Work and energy.	$m l^2 t^{-2}$
Resilience.	$m l^{-1} t^{-2}$
Power or activity.	$m l^2 t^{-3}$

II. Heat Units.

Name of Unit.	Conversion Factor.
Quantity of heat (thermal units).	$m\,\theta$
" " (thermometric units).	$l^3\,\theta$
" " (dynamical units).	$m\,l^2\,t^{-2}$
Coefficient of thermal expansion.	θ^{-1}
Conductivity (thermal units).	$m\,l^{-1}\,t^{-1}$
" (thermometric units), or diffusivity.	$l^2\,t^{-1}$
" (dynamical units).	$m\,l\,t^{-3}\,\theta^{-1}$
Thermal capacity.	m
Latent heat (thermal units).	θ
" " (dynamical units).	$l^2\,t^{-2}$
Joule's equivalent.	$l^2\,t^{-2}\,\theta$
Entropy (heat measured in thermal units).	m
" (" " " dynamical units).	$m\,l^2\,t^{-2}\,\theta$

III. Magnetic and Electric Units.

Name of Unit.	Conversion factor for electrostatic system.	Conversion factor for electromagnetic system.
Magnetic pole, or quantity of magnetism.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Density of surface distribution of magnetism.	$m^{\frac{1}{2}}\,l^{-\frac{3}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Intensity of magnetic field.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$
Magnetic potential.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$
Magnetic moment.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{5}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Intensity of magnetisation.	$m^{\frac{1}{2}}\,l^{-\frac{3}{2}}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,p^{\frac{1}{2}}$
Magnetic permeability.	1	1
Magnetic susceptibility and magnetic inductive capacity.	$l^{-2}\,t^2\,k^{-1}$	p
Quantity of electricity.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-1}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,p^{-\frac{1}{2}}$
Electric surface density and electric displacement.	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{-\frac{3}{2}}\,p^{-\frac{1}{2}}$
Intensity of electric field.	$m^{\frac{1}{2}}\,l^{-\frac{1}{2}}\,t^{-1}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-2}\,p^{\frac{1}{2}}$
Electric potential and e. m. f.	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,k^{-\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-2}\,p^{\frac{1}{2}}$
Capacity of a condenser.	$l\,k$	$l^{-1}\,t^2\,p^{-1}$
Inductive capacity.	k	$l^{-2}\,t^2\,p^{-1}$
Specific inductive capacity.	1	1
Electric current.	$m^{\frac{1}{2}}\,l^{\frac{3}{2}}\,t^{-2}\,k^{\frac{1}{2}}$	$m^{\frac{1}{2}}\,l^{\frac{1}{2}}\,t^{-1}\,p^{-\frac{1}{2}}$

FUNDAMENTAL AND DERIVED UNITS.

III. Magnetic and Electric Units.

Name of Unit.	Conversion factor for electrostatic system.	Conversion factor for electromagnetic system.
Conductivity.	$t^{-1} k$	$l^{-2} t p^{-1}$
Specific resistance.	$t k^{-1}$	$l^2 t^{-1} p$
Conductance.	$l t^{-1} k$	$l^{-1} t p^{-1}$
Resistance.	$l^{-1} t k^{-1}$	$l t^{-1} p$
Coefficient of self induction and coefficient of mutual induction.	$l^{-1} t^2 k^{-1}$	$l p$
Electrokinetic momentum.	$m^{\frac{1}{2}} l^{\frac{1}{2}} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{3}{2}} t^{-1} p^{\frac{1}{2}}$
Electromotive force at a point.	$m^{\frac{1}{2}} l^{-\frac{1}{2}} t^{-1} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-2} p^{\frac{1}{2}}$
Vector potential.	$m^{\frac{1}{2}} l^{-\frac{1}{2}} k^{-\frac{1}{2}}$	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1} p^{\frac{1}{2}}$
Thermoelectric height and specific heat of electricity.	$m^{\frac{1}{2}} l^{\frac{1}{2}} t^{-1} k^{-\frac{1}{2}} \theta^{-1}$	$m^{\frac{1}{2}} l^{\frac{3}{2}} t^{-2} p^{\frac{1}{2}} \theta^{-1}$
Coefficient of Peltier effect.	$m^{\frac{1}{2}} l^{-\frac{3}{2}} t k^{-\frac{1}{2}} \theta$	$m^{\frac{1}{2}} l^{-\frac{1}{2}} p^{\frac{1}{2}} \theta$

Table 2.

TABLES FOR CONVERTING U. S. WEIGHTS AND MEASURES.*

(1) CUSTOMARY TO METRIC.

LINEAR.

	Inches to millimeters.	Feet to meters.	Yards to meters.	Miles to kilometers.
1	25.4001	0.304801	0.914402	1.60935
2	50.8001	0.609601	1.828804	3.21869
3	76.2002	0.914402	2.743205	4.82804
4	101.6002	1.219202	3.657607	6.43739
5	127.0003	1.524003	4.572009	8.04674
6	152.4003	1.828804	5.486411	9.65608
7	177.8004	2.133604	6.400813	11.26543
8	203.2004	2.438405	7.315215	12.87478
9	228.6005	2.743205	8.229616	14.48412

CAPACITY.

	Fluid drams to milliliters or cubic centimeters.	Fluid ounces to milliliters.	Liquid quarts to liters.	Gallons to liters.
1	3.70	29.57	0.94633	3.78533
2	7.39	59.15	1.89267	7.57066
3	11.09	88.72	2.83900	11.35600
4	14.79	118.29	3.78533	15.14133
5	18.48	147.87	4.73167	18.92666
6	22.18	177.44	5.67800	22.71199
7	25.88	207.01	6.62433	26.49733
8	29.57	236.58	7.57066	30.28266
9	33.27	266.16	8.51700	34.06799

SQUARE.

	Square inches to square centimeters.	Square feet to square decimeters.	Square yards to square meters.	Acres to hectares.
1	6.452	9.290	0.836	0.4047
2	12.903	18.581	1.672	0.8094
3	19.355	27.871	2.508	1.2141
4	25.807	37.161	3.345	1.6187
5	32.258	46.452	4.181	2.0234
6	38.710	55.742	5.017	2.4281
7	45.161	65.032	5.853	2.8328
8	51.613	74.323	6.689	3.2375
9	58.065	83.613	7.525	3.6422

WEIGHT.

	Grains to milligrams.	Avoirdupois ounces to grams.	Avoirdupois pounds to kilograms.	Troy ounces to grams.
1	64.7989	28.3495	0.45359	31.10348
2	129.5978	56.6991	0.90718	62.20696
3	194.3968	85.0486	1.36078	93.31044
4	259.1957	113.3981	1.81437	124.41392
5	323.9946	141.7476	2.26796	155.51740
6	388.7935	170.0972	2.72155	186.62088
7	453.5924	198.4467	3.17515	217.72437
8	518.3913	226.7962	3.62874	248.82785
9	583.1903	255.1457	4.08233	279.93133

CUBIC.

	Cubic inches to cubic centimeters.	Cubic feet to cubic meters.	Cubic yards to cubic meters.	Bushels to hectoliters.
1	16.387	0.02832	0.765	0.35239
2	32.774	0.05663	1.529	0.70479
3	49.161	0.08495	2.294	1.05718
4	65.549	0.11327	3.058	1.40957
5	81.936	0.14159	3.823	1.76196
6	98.323	0.16990	4.587	2.11436
7	114.710	0.19822	5.352	2.46675
8	131.097	0.22654	6.116	2.81914
9	147.484	0.25485	6.881	3.17154

1 Gunter's chain	=	20.1168	meters.
1 sq. statute mile	=	259.000	hectares.
1 fathom	=	1.829	meters.
1 nautical mile	=	1853.25	meters.
1 foot	=	0.304801	meter.
1 avoir. pound	=	453.5924277	grams.
15432.35639 grains	=	1.000	kilogram.

According to an executive order dated April 15, 1893, the United States yard is defined as 3600/3937 meter, and the avoirdupois pound as 1/2.20462 kilogram.

1 meter (international prototype) = 1553164.13 times the wave-length of the red Cd. line. Benoit, Fabry and Perot. C. R. 144, 1907 differs only in the decimal portion from the measure of Michelson and Benoit 14 years earlier.

The length of the nautical mile given above and adopted by the U. S. Coast and Geodetic Survey many years ago, is defined as that of a minute of arc of a great circle of a sphere whose surface equals that of the earth (Clarke's Spheroid of 1866).

* Quoted from sheets issued by the United States Bureau of Standards.

TABLES FOR CONVERTING U. S. WEIGHTS AND MEASURES.

(2) METRIC TO CUSTOMARY.

LINEAR.

	Meters to inches.	Meters to feet.	Meters to yards.	Kilometers to miles.
1	39.3700	3.28083	1.093611	0.62137
2	78.7400	6.56167	2.187222	1.24274
3	118.1100	9.84250	3.280833	1.86411
4	157.4800	13.12333	4.374444	2.48548
5	196.8500	16.40417	5.468056	3.10685
6	236.2200	19.68500	6.561667	3.72822
7	275.5900	22.96583	7.655278	4.34959
8	314.9600	26.24667	8.748889	4.97096
9	354.3300	29.52750	9.842500	5.59233

CAPACITY.

	Milliliters or cubic centimeters to fluid drams.	Centiliters to fluid ounces.	Liters to quarts.	Decaliters to gallons.	Hectoliters to bushels.
1	0.27	0.338	1.0567	2.6418	2.8378
2	0.54	0.676	2.1134	5.2836	5.6756
3	0.81	1.014	3.1701	7.9253	8.5135
4	1.08	1.353	4.2268	10.5671	11.3513
5	1.35	1.691	5.2836	13.2089	14.1891
6	1.62	2.029	6.3403	15.8507	17.0269
7	1.89	2.367	7.3970	18.4924	19.8647
8	2.16	2.705	8.4537	21.1342	22.7026
9	2.43	3.043	9.5104	23.7760	25.5404

SQUARE.

	Square centimeters to square inches.	Square meters to square feet.	Square meters to square yards.	Hectares to acres.
1	0.1550	10.764	1.196	2.471
2	0.3100	21.528	2.392	4.942
3	0.4650	32.292	3.588	7.413
4	0.6200	43.055	4.784	9.884
5	0.7750	53.819	5.980	12.355
6	0.9300	64.583	7.176	14.826
7	1.0850	75.347	8.372	17.297
8	1.2400	86.111	9.568	19.768
9	1.3950	96.875	10.764	22.239

WEIGHT.

	Milligrams to grains.	Kilograms to grains.	Hectograms to ounces avoirdupois.	Kilograms to pounds avoirdupois.
1	0.01543	15432.36	3.5274	2.20462
2	0.03086	30864.71	7.0548	4.40924
3	0.04630	46297.07	10.5822	6.61387
4	0.06173	61729.43	14.1096	8.81849
5	0.07716	77161.78	17.6370	11.02311
6	0.09259	92594.14	21.1644	13.22773
7	0.10803	108026.49	24.6918	15.43236
8	0.12346	123458.85	28.2192	17.63698
9	0.13889	138891.21	31.7466	19.84160

CUBIC.

	Cubic centimeters to cubic inches.	Cubic decimeters to cubic inches.	Cubic meters to cubic feet.	Cubic meters to cubic yards.
1	0.0610	61.023	35.314	1.308
2	0.1220	122.047	70.269	2.616
3	0.1831	183.070	105.943	3.924
4	0.2441	244.094	141.258	5.232
5	0.3051	305.117	176.572	6.540
6	0.3661	366.140	211.887	7.848
7	0.4272	427.164	247.201	9.156
8	0.4882	488.187	282.516	10.464
9	0.5492	549.210	317.830	11.771

WEIGHT.

	Quintals to pounds av.	Milliers or tonnes to pounds av.	Kilograms to ounces Troy.
1	220.46	2204.6	32.1507
2	440.92	4409.2	64.3015
3	661.39	6613.9	96.4522
4	881.85	8818.5	128.6030
5	1102.31	11023.1	160.7537
6	1322.77	13227.7	192.9045
7	1543.24	15432.4	225.0552
8	1763.70	17637.0	257.2059
9	1984.16	19841.6	289.3567

By the concurrent action of the principal governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilograms were prepared, from the other a definite number of meter bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot, in September, 1889, to the different governments, and are called National prototype standards. Those apportioned to the United States were received in 1890, and are kept at the Bureau of Standards in Washington, D. C.

The metric system was legalized in the United States in 1866.

The International Standard Meter is derived from the Mètre des Archives, and its length is defined by the distance between two lines at 0° Centigrade, on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogram is a mass of platinum-iridium deposited at the same place, and its weight in vacuo is the same as that of the Kilogram des Archives.

The liter is equal to the quantity of pure water at 4° C, 760 mm. Hg. pressure which weighs 1 kilogram = 1.000027 cu. dm. (Trav. et Mem. Bureau Intern. des P. et M. 14, 1910, Benoit.)

TABLE 3.

EQUIVALENTS OF METRIC AND BRITISH IMPERIAL WEIGHTS AND MEASURES.*

(1) METRIC TO IMPERIAL.

LINEAR MEASURE.

1 millimeter (mm.) (.001 m.)	= 0.03937 in.
1 centimeter (.01 m.)	= 0.39370 "
1 decimeter (.1 m)	= 3.93701 "
1 METER (m.)	= 39.370113 " 3.280843 ft. 1.09361425 yds.
1 dekameter (10 m.)	= 10.93614 "
1 hectometer (100 m.)	= 109.361425 "
1 kilometer (1,000 m.)	= 0.62137 mile.
1 myriameter (10,000 m.)	= 6.21372 miles.
1 micron	= 0.001 mm.

SQUARE MEASURE.

1 sq. centimeter	= 0.1550 sq. in.
1 sq. decimeter (100 sq. centm.)	= 15.500 sq. in.
1 sq. meter or centiare (100 sq. dcm.)	= 10.7639 sq. ft. 1.1960 sq. yds.
1 ARE (100 sq. m.)	= 119.60 sq. yds.
1 hectare (100 ares or 10,000 sq. m.)	= 2.4711 acres.

CUBIC MEASURE.

1 cub. centimeter (c.c.) (1,000 cubic millimeters)	= 0.0610 cub. in.
1 cub. decimeter (c.d.) (1,000 cubic centimeters)	= 61.024 " "
1 CUB. METER or stere (1,000 c.d.)	= 35.3148 cub. ft. 1.307954 cub. yds.

MEASURE OF CAPACITY.

1 milliliter (ml.) (.001 liter)	= 0.0610 cub. in.
1 centiliter (.01 liter)	= 0.61024 " " 0.070 gill.
1 deciliter (.1 liter)	= 0.176 pint.
1 LITER (1,000 cub. centimeters or 1 cub. decimeter)	= 1.75980 pints.
1 dekaliter (10 liters)	= 2.200 gallons.
1 hectoliter (100 ")	= 2.75 bushels.
1 kiloliter (1,000 ")	= 3.437 quarters.

APOTHECARIES' MEASURE.

1 cubic centimeter (1 gram w't)	= 0.03520 fluid ounce. 0.28157 fluid drachm. 15.43236 grains weight.
1 cub. millimeter	= 0.01693 minim.

AVOIRDUPOIS WEIGHT.

1 milligram (mgr.)	= 0.01543 grain.
1 centigram (.01 gram.)	= 0.15432 "
1 decigram (.1 ")	= 1.54324 grains.
1 GRAM	= 15.43236 "
1 dekagram (10 gram.)	= 5.64383 drams.
1 hectogram (100 ")	= 3.52739 oz.
1 KILOGRAM (1,000 ")	= 2.2046223 lb. 15432.3564 grains.
1 myriagram (10 kilog.)	= 22.04622 lbs.
1 quintal (100 ")	= 1.96841 cwt.
1 millier or tonne (1,000 kilog.)	= 0.9842 ton.

TROY WEIGHT.

1 GRAM	= 0.03215 oz. Troy. 0.64301 pennyweight. 15.43236 grains.

APOTHECARIES' WEIGHT.

1 GRAM	= 0.25721 drachm. 0.77162 scruple. 15.43236 grains.

NOTE.—The METER is the length, at the temperature of 0° C., of the platinum-iridium bar deposited at the International Bureau of Weights and Measures at Sèvres, near Paris, France.

The present legal equivalent of the meter is 39.370113 inches, as above stated.

The KILOGRAM is the mass of a platinum-iridium weight deposited at the same place.

The LITER contains one kilogram weight of distilled water at its maximum density (4° C.), the barometer being at 760 millimeters.

*In accordance with the schedule adopted under the Weights and Measures (metric system) Act, 1897.

TABLE 3.

EQUIVALENTS OF METRIC AND BRITISH IMPERIAL WEIGHTS AND MEASURES.

(2) METRIC TO IMPERIAL.

	LINEAR MEASURE.					MEASURE OF CAPACITY.			
	Millimeters to inches.	Meters to feet.	Meters to yards.	Kilometers to miles.		Liters to pints.	Dekaliters to gallons.	Hectoliters to bushels.	Kiloliters to quarters.
1	0.03937011	3.28084	1.09361	0.62137	1	1.75980	2.19975	2.74969	3.43712
2	0.07874023	6.56169	2.18723	1.24274	2	3.51961	4.39951	5.49938	6.87423
3	0.11811034	9.84253	3.28084	1.86412	3	5.27941	6.59926	8.24908	10.31135
4	0.15748045	13.12337	4.37446	2.48549	4	7.03921	8.79902	10.99877	13.74846
5	0.19685056	16.40421	5.46807	3.10686	5	8.79902	10.99877	13.74846	17.18558
6	0.23622068	19.68506	6.56169	3.72823	6	10.55882	13.19852	16.49815	20.62269
7	0.27559079	22.96590	7.65530	4.34960	7	12.31862	15.39828	19.24785	24.05981
8	0.31496090	26.24674	8.74891	4.97097	8	14.07842	17.59803	21.99754	27.49692
9	0.35433102	29.52758	9.84253	5.59235	9	15.83823	19.79778	24.74723	30.93404

	SQUARE MEASURE.					WEIGHT (AVOIRDUPOIS).			
	Square centimeters to square inches.	Square meters to square feet.	Square meters to square yards.	Hectares to acres.		Milligrams to grains.	Kilograms to grains.	Kilograms to pounds.	Quintals to hundredweights.
1	0.15500	10.76393	1.19599	2.4711	1	0.01543	15432.356	2.20462	1.96841
2	0.31000	21.52786	2.39198	4.9421	2	0.03086	30864.713	4.40924	3.93683
3	0.46500	32.29179	3.58798	7.4132	3	0.04630	46297.069	6.61387	5.90524
4	0.62000	43.05572	4.78397	9.8842	4	0.06173	61729.426	8.81849	7.87365
5	0.77500	53.81965	5.97996	12.3553	5	0.07716	77161.782	11.02311	9.84206
6	0.93000	64.58357	7.17595	14.8263	6	0.09259	92594.138	13.22773	11.81048
7	1.08500	75.34750	8.37194	17.2974	7	0.10803	108026.495	15.43236	13.77889
8	1.24000	86.11143	9.56794	19.7685	8	0.12346	123458.851	17.63698	15.74730
9	1.39501	96.87536	10.76393	22.2395	9	0.13889	138891.208	19.84160	17.71572

	CUBIC MEASURE.			APOTHECARIES' MEASURE.		AVOIRDUPOIS (*cont.*)	TROY WEIGHT.		APOTHECARIES' WEIGHT.
	Cubic decimeters to cubic inches.	Cubic meters to cubic feet.	Cubic meters to cubic yards.	Cub. centimeters to fluid drachms.		Milliers or tonnes to tons.	Grams to ounces Troy.	Grams to pennyweights.	Grams to scruples.
1	61.02390	35.31476	1.30795	0.28157	1	0.98421	0.03215	0.64301	0.77162
2	122.04781	70.62952	2.61591	0.56314	2	1.96841	0.06430	1.28603	1.54324
3	183.07171	105.94428	3.92386	0.84471	3	2.95262	0.09645	1.92904	2.31485
4	244.09561	141.25904	5.23182	1.12627	4	3.93683	0.12860	2.57206	3.08647
5	305.11952	176.57379	6.53977	1.40784	5	4.92103	0.16075	3.21507	3.85809
6	366.14342	211.88855	7.84772	1.68941	6	5.90524	0.19290	3.85809	4.62971
7	427.16732	247.20331	9.15568	1.97098	7	6.88944	0.22506	4.50110	5.40132
8	488.19123	282.51807	10.46363	2.25255	8	7.87365	0.25721	5.14412	6.17294
9	549.21513	317.83283	11.77159	2.53412	9	8.85786	0.28936	5.78713	6.94456

TABLE 3.

EQUIVALENTS OF BRITISH IMPERIAL AND METRIC WEIGHTS AND MEASURES.

(3) IMPERIAL TO METRIC.

LINEAR MEASURE.

1 inch . . . . . . =	25.400 millimeters.
1 foot (12 in.) . . =	0.30480 meter.
1 YARD (3 ft.) . . =	0.914399 "
1 pole ($5\frac{1}{2}$ yd.) . . =	5.0292 meters.
1 chain (22 yd. or 100 links) =	20.1168 "
1 furlong (220 yd.) =	201.168 "
1 mile (1,760 yd.) . =	1.6093 kilometers.

SQUARE MEASURE.

1 square inch . . =	6.4516 sq. centimeters.
1 sq. ft. (144 sq. in.) =	9.2903 sq. decimeters.
1 SQ. YARD (9 sq. ft.) =	0.836126 sq. meters.
1 perch ($30\frac{1}{4}$ sq. yd.) =	25.293 sq. meters.
1 rood (40 perches) =	10.117 ares.
1 ACRE (4840 sq. yd.) =	0.40468 hectare.
1 sq. mile (640 acres) =	259.00 hectares.

CUBIC MEASURE.

1 cub. inch =	16.387 cub. centimeters.
1 cub. foot (1728 cub. in.) =	0.0283317 cub. meter, or 28.317 cub. decimeters.
1 CUB. YARD (27 cub. ft.) =	0.76455 cub. meter.

APOTHECARIES' MEASURE.

1 gallon (8 pints or 160 fluid ounces) =	4.5459631 liters.
1 fluid ounce, f ℥ (8 drachms) =	28.4123 cubic centimeters.
1 fluid drachm, f ʒ (60 minims) =	3.5515 cubic centimeters.
1 minim, ♏ (0.91146 grain weight) =	0.05919 cubic centimeters.

NOTE. — The Apothecaries' gallon is of the same capacity as the Imperial gallon.

MEASURE OF CAPACITY.

1 gill . . . . =	1.42 deciliters.
1 pint (4 gills) . . . =	0.568 liter.
1 quart (2 pints) . . =	1.136 liters.
1 GALLON (4 quarts) =	4.5459631 "
1 peck (2 galls.) . . =	9.092 "
1 bushel (8 galls.) . =	3.637 dekaliters.
1 quarter (8 bushels) =	2.909 hectoliters.

AVOIRDUPOIS WEIGHT.

1 grain . . . . . . =	64.8 milligrams.
1 dram . . . . . . =	1.772 grams.
1 ounce (16 dr.) . . =	28.350 "
1 POUND (16 oz. or 7,000 grains) =	0.45359243 kilogr.
1 stone (14 lb.) . . =	6.350 "
1 quarter (28 lb.) . =	12.70 "
1 hundredweight (112 lb.) =	50.80 " 0.5080 quintal.
1 ton (20 cwt.) . =	1.0160 tonnes or 1016 kilograms.

TROY WEIGHT.

1 Troy OUNCE (480 grains avoir.) =	31.1035 grams.
1 pennyweight (24 grains) =	1.5552 "

NOTE. — The Troy grain is of the same weight as the Avoirdupois grain.

APOTHECARIES' WEIGHT.

1 ounce (8 drachms) =	31.1035 grams.
1 drachm, ʒ i (3 scruples) =	3.888 "
1 scruple, ℈i (20 grains) =	1.296 "

NOTE. — The Apothecaries' ounce is of the same weight as the Troy ounce. The Apothecaries' grain is also of the same weight as the Avoirdupois grain.

NOTE. — The YARD is the length at 62° Fahr., marked on a bronze bar deposited with the Board of Trade.

The POUND is the weight of a piece of platinum weighed in vacuo at the temperature of 0° C., and which is also deposited with the Board of Trade.

The GALLON contains 10 lb. weight of distilled water at the temperature of 62° Fahr., the barometer being at 30 inches.

Table 3.

EQUIVALENTS OF BRITISH IMPERIAL AND METRIC WEIGHTS AND MEASURES.

(4) IMPERIAL TO METRIC.

LINEAR MEASURE.

	Inches to centimeters.	Feet to meters.	Yards to meters.	Miles to kilometers.
1	2.539998	0.30480	0.91440	1.60934
2	5.079996	0.60960	1.82880	3.21869
3	7.619993	0.91440	2.74320	4.82803
4	10.159991	1.21920	3.65760	6.43737
5	12.699989	1.52400	4.57200	8.04671
6	15.239987	1.82880	5.48640	9.65606
7	17.779984	2.13360	6.40080	11.26540
8	20.319982	2.43840	7.31519	12.87474
9	22.859980	2.74320	8.22959	14.48408

MEASURE OF CAPACITY.

	Quarts to liters.	Gallons to liters.	Bushels to dekaliters.	Quarters to hectoliters.
1	1.13649	4.54596	3.63677	2.90942
2	2.27298	9.09193	7.27354	5.81883
3	3.40947	13.63789	10.91031	8.72825
4	4.54596	18.18385	14.54708	11.63767
5	5.68245	22.72982	18.18385	14.54708
6	6.81894	27.27578	21.82062	17.45650
7	7.95544	31.82174	25.45739	20.36591
8	9.09193	36.36770	29.09416	23.27533
9	10.22842	40.91367	32.73093	26.18475

SQUARE MEASURE.

	Square inches to square centimeters.	Square feet to square decimeters.	Square yards to square meters.	Acres to hectares.
1	6.45159	9.29029	0.83613	0.40468
2	12.90318	18.58058	1.67225	0.80937
3	19.35477	27.87086	2.50838	1.21405
4	25.80636	37.16115	3.34450	1.61874
5	32.25794	46.45144	4.18063	2.02342
6	38.70953	55.74173	5.01676	2.42811
7	45.16112	65.03201	5.85288	2.83279
8	51.61271	74.32230	6.68901	3.23748
9	58.06430	83.61259	7.52513	3.64216

WEIGHT (Avoirdupois).

	Graios to milligrams.	Ounces to grams.	Pounds to kilograms.	Hundredweights to quintals.
1	64.79892	28.34953	0.45359	0.50802
2	129.59784	56.69905	0.90718	1.01605
3	194.39675	85.04858	1.36078	1.52407
4	259.19567	113.39811	1.81437	2.03209
5	323.99459	141.74763	2.26796	2.54012
6	388.79351	170.09716	2.72155	3.04814
7	453.59243	198.44669	3.17515	3.55616
8	518.39135	226.79621	3.62874	4.06419
9	583.19026	255.14574	4.08233	4.57221

CUBIC MEASURE. / Apothecaries' Measure.

	Cubic inches to cubic centimeters.	Cubic feet to cubic meters.	Cubic yards to cubic meters.	Fluid drachms to cubic centimeters.
1	16.38702	0.02832	0.76455	3.55153
2	32.77404	0.05663	1.52911	7.10307
3	49.16106	0.08495	2.29366	10.65460
4	65.54808	0.11327	3.05821	14.20613
5	81.93511	0.14158	3.82276	17.75767
6	98.32213	0.16990	4.58732	21.30920
7	114.70915	0.19822	5.35187	24.86074
8	131.09617	0.22653	6.11642	28.41227
9	147.48319	0.25485	6.88098	31.96380

Avoirdupois (*cont.*). / Troy Weight. / Apothecaries' Weight.

	Avoirdupois (*cont.*)	Troy Weight.		Apothecaries' Weight.
	Tons to milliers or tonnes.	Ounces to grams.	Pennyweights to grams.	Scruples to grams.
1	1.01605	31.10348	1.55517	1.29598
2	2.03209	62.20696	3.11035	2.59196
3	3.04814	93.31044	4.66552	3.88794
4	4.06419	124.41392	6.22070	5.18391
5	5.08024	155.51740	7.77587	6.47989
6	6.09628	186.62088	9.33104	7.77587
7	7.11233	217.72437	10.88622	9.07185
8	8.12838	248.82785	12.44139	10.36783
9	9.14442	279.93133	13.99657	11.66381

VOLUME OF A GLASS VESSEL FROM THE WEIGHT OF ITS EQUIVALENT VOLUME OF MERCURY OR WATER.

If a glass vessel contains at t° C, P grammes of mercury, weighted with brass weights in air at 760 mm. pressure, then its volume in c. cm.

at the same temperature, t, : $V = PR = P\frac{p}{d}$,

at another temperature, t_1, : $V = PR_1 = Pp/d\,\{1 + \gamma\,(t_1 - t)\}$

p = the weight, reduced to vacuum, of the mass of mercury or water which, weighed with brass weights, equals 1 gram;

d = the density of mercury or water at t° C,

and $\gamma = 0.000\,025$, is the cubical expansion coefficient of glass.

Temperature t	WATER.			MERCURY.		
	R.	R_1, $t_1 = 10°$.	R_1, $t_1 = 20°$.	R.	R_1, $t_1 = 10°$.	R_1, $t_1 = 20°$.
0°	1.001192	1.001443	1.001693	0.0735499	0.0735683	0.0735867
1	1133	1358	1609	5633	5798	5982
2	1092	1292	1542	5766	5914	6098
3	1068	1243	1493	5900	6029	6213
4	1060	1210	1460	6033	6144	6328
5	1068	1193	1443	6167	6259	6443
6	1.001092	1.001192	1.001442	0.0736301	0.0736374	0.0736558
7	1131	1206	1456	6434	6490	6674
8	1184	1234	1485	6568	6605	6789
9	1252	1277	1527	6702	6720	6904
10	1333	1333	1584	6835	6835	7020
11	1.001428	1.001403	1.001653	0.0736969	0.0736951	0.0737135
12	1536	1486	1736	7103	7066	7250
13	1657	1582	1832	7236	7181	7365
14	1790	1690	1940	7370	7297	7481
15	1935	1810	2060	7504	7412	7596
16	1.002092	1.001942	1.002193	0.0737637	0.0737527	0.0737711
17	2261	2086	2337	7771	7642	7826
18	2441	2241	2491	7905	7757	7941
19	2633	2407	2658	8039	7872	8057
20	2835	2584	2835	8172	7988	8172
21	1.003048	1.002772	1.003023	0.0738306	0.0738103	0.0738288
22	3271	2970	3220	8440	8218	8403
23	3504	3178	3429	8573	8333	8518
24	3748	3396	3647	8707	8449	8633
25	4001	3624	3875	8841	8564	8748
26	1.004264	1.003862	1.004113	0.0738974	0.0738679	0.0738864
27	4537	4110	4361	9108	8794	8979
28	4818	4366	4616	9242	8910	9094
29	5110	4632	4884	9376	9025	9210
30	5410	4908	5159	9510	9140	9325

Taken from Landolt, Börnstein, and Meyerhoffer's Physikalisch-Chemische Tabellen.

TABLE 5.

DERIVATIVES AND INTEGRALS.*

$d\,ax$	$= a\,dx$	$\int x^n\,dx$	$= \frac{x^{n+1}}{n+1}$, unless $n = -1$
$d\,u\,v$	$= \left(u\frac{dv}{dx} + v\frac{du}{dx}\right)dx$	$\int \frac{dx}{x}$	$= \log x$
$d\,\frac{u}{v}$	$= \left(\frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}\right)dx$	$\int e^x\,dx$	$= e^x$
$d\,x^n$	$= nx^{n-1}\,dx$	$\int e^{ax}dx$	$= \frac{1}{a}\,e^{ax}$
$d\,f(u)$	$= d\,\frac{f(u)}{du} \cdot \frac{du}{dx} \cdot dx$	$\int x\,e^{ax}\,dx$	$= \frac{e^{ax}}{a^2}\,(ax - 1)$
$d\,e^x$	$= e^x\,dx$	$\int \log x\,dx$	$= x\log x - x$
$d\,e^{ax}$	$= a\,e^{ax}\,dx$	$\int u\,dv$	$= u\,v - \int v\,du$
$d\log_e x$	$= \frac{1}{x}\,dx$	$\int (a+bx)^n\,dx$	$= \frac{(a+bx)^{n+1}}{(n+1)b}$
$d\,x^x$	$= x^x\,(1 + \log_e x)$		
$d\sin x$	$= \cos x\,dx$	$\int (a^2+x^2)^{-1}\,dx$	$= \frac{1}{a}\tan^{-1}\frac{x}{a} =$
			$\frac{1}{a}\sin^{-1}\frac{x}{\sqrt{x^2+a^2}}$
$d\cos x$	$= -\sin x\,dx$	$\int (a^2-x^2)^{-1}dx$	$= \frac{1}{2a}\log\frac{a+x}{a-x}$
$d\tan x$	$= \sec^2 x\,dx$	$\int (a^2-x^2)^{-\frac{1}{2}}\,dx$	$= \sin^{-1}\frac{x}{a}$, or $-\cos^{-1}\frac{x}{a}$
$d\cot x$	$= -\csc^2 x\,dx$	$\int x(a^2 \pm x^2)^{-\frac{1}{2}}\,dx$	$= \pm(a^2 \pm x^2)^{\frac{1}{2}}$
$d\sec x$	$= \tan x \sec x\,dx$	$\int \sin^2 x\,dx$	$= -\frac{1}{2}\cos x \sin x + \frac{1}{2}x$
$d\csc x$	$= -\cot x\,.\,\mathrm{scs}\,x\,dx$	$\int \cos^2 x\,dx$	$= \frac{1}{2}\sin x \cos x + \frac{1}{2}x$
$d\sin^{-1} x$	$= (1-x^2)^{-\frac{1}{2}}\,dx$	$\int \sin x \cos x\,dx$	$= \frac{1}{2}\sin^2 x$
$d\cos^{-1} x$	$= -(1-x^2)^{-\frac{1}{2}}\,dx$	$\int (\sin x \cos x)^{-1}\,dx$	$= \log\tan x$
$d\tan^{-1} x$	$= (1+x^2)^{-1}\,dx$	$\int \tan x\,dx$	$= -\log\cos x$
$d\cot^{-1} x$	$= -(1+x^2)^{-1}\,dx$	$\int \tan^2 x\,dx$	$= \tan x - x$
$d\sec^{-1} x$	$= x^{-1}\,(x^2-1)^{-\frac{1}{2}}\,dx$	$\int \cot x\,dx$	$= \log\sin x$
$d\csc^{-1} x]$	$= -x^{-1}\,(x^2-1)^{-\frac{1}{2}}\,dx$	$\int \cot^2 x\,dx$	$= -\cot x - x$
$d\sinh x$	$= \cosh x\,dx$	$\int \csc x\,dx$	$= \log\tan\frac{1}{2}x$
$d\cosh x$	$= \sinh x\,dx$	$\int x \sin x\,dx$	$= \sin x - x\cos x$
$d\tanh x$	$= \mathrm{sech}^2\,x\,dx$	$\int x \cos x\,dx$	$= \cos x + x\sin x$
$d\coth x$	$= -\mathrm{csch}^2\,x\,dx$	$\int \tanh x\,dx$	$= \log\cosh x$
$d\,\mathrm{sech}\,x$	$= -\mathrm{sech}\,x\tanh dx$	$\int \coth x\,dx$	$= \log\sinh x$
$d\,\mathrm{csch}\,x$	$= -\mathrm{csch}\,x\,.\,\coth x\,dx$	$\int \mathrm{sech}\,x\,dx$	$= 2\tan^{-1} e^x = \mathrm{gd}\,u$
$d\sinh^{-1} x$	$= (x^2+1)^{-\frac{1}{2}}\,dx$	$\int \mathrm{csch}\,x\,dx$	$= \log\tanh\frac{x}{2}$
$d\cosh^{-1} x$	$= (x^2-1)^{-\frac{1}{2}}\,dx$	$\int x \sinh x\,dx$	$= x\cosh x - \sinh x$
$d\tanh^{-1} x$	$= (1-x^2)^{-1}\,dx$	$\int x \cosh x\,dx$	$= x\sinh x - \cosh x$
$d\coth^{-1} x$	$= (1-x^2)^{-1}\,dx$	$\int \sinh^2 x\,dx$	$= \frac{1}{2}(\sinh x \cosh x - x)$
$d\,\mathrm{sech}^{-1}\,x$	$= -x^{-1}\,(1-x^2)^{-\frac{1}{2}}\,dx$	$\int \cosh^2 x\,dx$	$= \frac{1}{2}(\sinh x \cosh x + x)$
$d\,\mathrm{csch}^{-1}\,x$	$= -x^{-1}\,(x^2+1)^{-\frac{1}{2}}$	$\int \sinh x \cosh x\,dx$	$= \frac{1}{4}\cosh(2x)$

* See also accompanying table of derivatives. For example : $\int$ cos. $x\,dx$ = sin. x + constant.

TABLE 6.
SERIES.

$$(x+y)^n = x^n + \frac{n}{1} x^{n-1} y + \frac{n(n-1)}{2!} x^{n-2} y^2 + \ldots$$
$$\frac{n(n-1)\ldots(n-m+1)}{m!} x^{n-m} y^m + \ldots \qquad (y^2<x^2)$$

$$(1 \pm x)^n = 1 \pm nx + \frac{n(n-1)x^2}{2!} \pm \frac{n(n-1)(n-2)x^2}{3!} + \ldots + \frac{(\pm 1)^k n!\, x^k}{(n-k)!\, k!} + \ldots \quad (x^2<1)$$

$$(1 \pm x)^{-n} = 1 \mp nx + \frac{n(n+1)}{2!} x^2 \mp \frac{n(n+1)(n+2)x^3}{3!} + \ldots$$
$$(\mp 1)^k \frac{(n+k-1)\, x^k}{(n-1)!\, k!} + \ldots \quad (x^2<1)$$

$$(1 \pm x)^{-1} = 1 \mp x + x^2 \mp x^3 + x^4 \mp x^5 + \ldots \qquad (x^2<1)$$

$$(1 \pm x)^{-2} = 1 \mp 2x + 3x^2 \mp 4x^3 + 5x^4 \mp 6x^5 + \ldots \qquad (x^2<1)$$

$$f(x+h) = f(x) + h f'(x) + \frac{h^2}{2!} f''(x) + \ldots + \frac{h^n}{n!} f^{(n)}(x) + \ldots$$ Taylor's series.

$$f(x) = f(0) + \frac{x}{1} f'(0) + \frac{x^2}{2!} f''(0) + \ldots \frac{x^n}{n!} f^{(n)}(0) + \ldots$$ Maclaurin's series.

$$e = \lim\left(1+\frac{1}{n}\right)^n = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \ldots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \ldots \qquad (x^2<\infty)$$

$$a^x = 1 + x \log a + \frac{(x \log a)^2}{2!} + \frac{(x \log a)^3}{3!} + \ldots. \qquad (x^2<\infty)$$

$$\log x = \frac{x-1}{x} + \frac{1}{2}\left(\frac{x-1}{x}\right)^2 + \frac{1}{3}\left(\frac{x-1}{x}\right)^3 + \ldots \qquad (x>\tfrac{1}{2})$$
$$= (x-1) - \tfrac{1}{2}(x-1)^2 + \tfrac{1}{3}(x-1)^3 - \ldots \qquad (2>x>0)$$
$$= 2\left[\frac{x-1}{x+1} + \frac{1}{3}\left(\frac{x-1}{x+1}\right)^3 + \frac{1}{5}\left(\frac{x-1}{x+1}\right)^5 + \ldots.\right] \qquad (x>0)$$

$$\log(1+x) = x - \tfrac{1}{2}x^2 + \tfrac{1}{3}x^3 - \tfrac{1}{4}x^4 + \ldots. \qquad (x^2<1)$$

$$\sin x = \frac{1}{2i}(e^{ix} - e^{-ix}) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \ldots \qquad (x^2<\infty)$$

$$\cos x = \frac{1}{2}(e^{ix} + e^{-ix}) = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \ldots = 1 - \text{versin}\, x \qquad (x^2<\infty)$$

$$\tan x = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \frac{62}{2835} x^9 + \ldots \qquad \left(x^2<\frac{\pi^2}{4}\right)$$

$$\sin^{-1} x = \frac{\pi}{2} - \cos.^{-1} x = x + \frac{x^3}{6} + \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{x^5}{5} + \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{5}{6}\cdot\frac{x^7}{7} + \ldots \qquad (x^2<1)$$

$$\tan^{-1} x = \frac{\pi}{2} - \cot.^{-1} x = x - \frac{1}{3}x^3 + \frac{1}{5}x^5 - \frac{1}{7}x^7 + \ldots \qquad (x^2<1)$$
$$= \frac{\pi}{2} - \frac{1}{x} + \frac{1}{3x^3} - \frac{1}{5x^5} + \ldots \qquad (x^2>1)$$

$$\sinh x = \frac{1}{2}(e^x - e^{-x}) = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \ldots \qquad (x^2<\infty)$$

SERIES.

$$\cosh x = \frac{1}{2}(e^x + e^{-x}) = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \dots \qquad (x^2 < \infty)$$

$$\tanh x = x - \frac{1}{3}x^3 + \frac{2}{15}x^5 - \frac{17}{315}x^7 + \dots \qquad (x^2 < \tfrac{1}{4}\pi^2)$$

$$\sinh^{-1} x = x - \frac{1}{2}\frac{x^3}{3} + \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{x^5}{5} - \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{5}{6}\frac{x^7}{7} + \dots \qquad (x^2 < 1)$$

$$= \log 2x + \frac{1}{2}\frac{1}{2x^2} - \frac{1}{2}\frac{3}{4}\frac{1}{4x^4} + \frac{1}{2}\frac{3}{4}\frac{5}{6}\frac{1}{6x^6} - \dots \qquad (x^2 > 1)$$

$$\cosh^{-1} x = \log 2x - \frac{1}{2}\frac{1}{2x^2} - \frac{1}{2}\frac{3}{4}\frac{1}{4x^4} - \frac{1}{2}\frac{3}{4}\frac{5}{6}\frac{1}{6x^6} - \dots \qquad (x^2 > 1)$$

$$\tanh^{-1} x = x + \frac{1}{3}x^3 + \frac{1}{5}x^5 + \frac{1}{7}x^7 + \dots \qquad (x^2 < 1)$$

$$\text{gd}\, x = \phi = x - \frac{1}{6}x^3 + \frac{1}{24}x^5 - \frac{61}{5040}x^7 + \dots \qquad (x \text{ small})$$

$$= \frac{\pi}{2} - \text{sech.}\, x - \frac{1}{2}\frac{\text{sech}^3 x}{3} - \frac{1}{2}\frac{3}{4}\frac{\text{sech}^5 x}{5} - \dots \qquad (x \text{ large})$$

$$x = \text{gd}^{-1}\phi = \phi + \frac{1}{6}\phi^3 + \frac{1}{24}\phi^5 + \frac{61}{5040}\phi^7 + \dots \qquad \left(\phi < \frac{\pi}{2}\right)$$

$$f(x) = \frac{1}{2}b_0 + b_1\cos\frac{\pi x}{c} + b_2\cos\frac{2\pi x}{c} + \dots$$

$$+ a_1\sin\frac{\pi x}{c} + a_2\cos\frac{2\pi x}{c} + \dots \qquad (-c < x < c)$$

$$a_m = \frac{1}{c}\int_{-c}^{+c} f(x)\sin\frac{m\pi x}{c}\,dx$$

$$b_m = \frac{1}{c}\int_{-c}^{+c} f(x)\cos\frac{m\pi x}{c}\,dx$$

TABLE 7.—MATHEMATICAL CONSTANTS.

	Numbers.	Logarithms.
$e = 2.71828\ 18285$	$\pi = 3.14159\ 26536$	0.49714 98727
$e^{-1} = 0.36787\ 94412$	$\pi^2 = 9.86960\ 44011$	0.99429 97454
$M = \log_{10} e = 0.43429\ 44819$	$\frac{1}{\pi} = 0.31830\ 98862$	9.50285 01273
$(M)^{-1} = \log_e 10 = 2.30258\ 50930$	$\sqrt{\pi} = 1.77245\ 38509$	0.24857 49363
$\log_{10}\log_{10} e = 9.63778\ 43113$	$\frac{\sqrt{\pi}}{2} = 0.88622\ 69255$	9.94754 49407
$\log_{10} 2 = 0.30102\ 99957$	$\frac{1}{\sqrt{\pi}} = 0.56418\ 95835$	9.75142 50637
$\log_e 2 = 0.69314\ 71806$	$\frac{2}{\sqrt{\pi}} = 1.12837\ 91671$	0.05245 50593
$\log_{10} x = M.\log_e x$	$\sqrt{\frac{\pi}{2}} = 1.25331\ 41373$	0.09805 99385
$\log_B x = \log_e x.\ \log_B e$	$\sqrt{\frac{2}{\pi}} = 0.79788\ 45608$	9.90194 00615
$= \log_e x \div \log_e B$	$\frac{\pi}{4} = 0.78539\ 81634$	9.89508 98814
$\log_e \pi = 1.14472\ 98858$	$\frac{\sqrt{\pi}}{4} = 0.44311\ 34627$	9.64651 49450
$\rho = 0.47693\ 62762$	$\frac{4}{3}\pi = 4.18879\ 02048$	0.62208 86093
$\log \rho = 9.67846\ 03565$	$\frac{e}{\sqrt{2\pi}} = 1.08443\ 75514$	0.03520 45477

VALUES OF RECIPROCALS, SQUARES, CUBES, SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
10	100.000	100	1000	3.1623	**65**	15.3846	4225	274625	8.0623
11	90.9091	121	1331	3.3166	66	15.1515	4356	287496	8.1240
12	83.3333	144	1728	3.4641	67	14.9254	4489	300763	8.1854
13	76.9231	169	2197	3.6056	68	14.7059	4624	314432	8.2462
14	71.4286	196	2744	3.7417	69	14.4928	4761	328509	8.3066
15	66.6667	225	3375	3.8730	**70**	14.2857	4900	343000	8.3666
16	62.5000	256	4096	4.0000	71	14.0845	5041	357911	8.4261
17	58.8235	289	4913	4.1231	72	13.8889	5184	373248	8.4853
18	55.5556	324	5832	4.2426	73	13.6986	5329	389017	8.5440
19	52.6316	361	6859	4.3589	74	13.5135	5476	405224	8.6023
20	50.0000	400	8000	4.4721	**75**	13.3333	5625	421875	8.6603
21	47.6190	441	9261	4.5826	76	13.1579	5776	438976	8.7178
22	45.4545	484	10648	4.6904	77	12.9870	5929	456533	8.7750
23	43.4783	529	12167	4.7958	78	12.8205	6084	474552	8.8318
24	41.6667	576	13824	4.8990	79	12.6582	6241	493039	8.8882
25	40.0000	625	15625	5.0000	**80**	12.5000	6400	512000	8.9443
26	38.4615	676	17576	5.0990	81	12.3457	6561	531441	9.0000
27	37.0370	729	19683	5.1962	82	12.1951	6724	551368	9.0554
28	35.7143	784	21952	5.2915	83	12.0482	6889	571787	9.1104
29	34.4828	841	24389	5.3852	84	11.9048	7056	592704	9.1652
30	33.3333	900	27000	5.4772	**85**	11.7647	7225	614125	9.2195
31	32.2581	961	29791	5.5678	86	11.6279	7396	636056	9.2736
32	31.2500	1024	32768	5.6569	87	11.4943	7569	658503	9.3274
33	30.3030	1089	35937	5.7446	88	11.3636	7744	681472	9.3808
34	29.4118	1156	39304	5.8310	89	11.2360	7921	704969	9.4340
35	28.5714	1225	42875	5.9161	**90**	11.1111	8100	729000	9.4868
36	27.7778	1296	46656	6.0000	91	10.9890	8281	753571	9.5394
37	27.0270	1369	50653	6.0828	92	10.8696	8464	778688	9.5917
38	26.3158	1444	54872	6.1644	93	10.7527	8649	804357	9.6437
39	25.6410	1521	59319	6.2450	94	10.6383	8836	830584	9.6954
40	25.0000	1600	64000	6.3246	**95**	10.5263	9025	857375	9.7468
41	24.3902	1681	68921	6.4031	96	10.4167	9216	884736	9.7980
42	23.8095	1764	74088	6.4807	97	10.3093	9409	912673	9.8489
43	23.2558	1849	79507	6.5574	98	10.2041	9604	941192	9.8995
44	22.7273	1936	85184	6.6332	99	10.1010	9801	970299	9.9499
45	22.2222	2025	91125	6.7082	**100**	10.0000	10000	1000000	10.0000
46	21.7391	2116	97336	6.7823	101	9.90099	10201	1030301	10.0499
47	21.2766	2209	103823	6.8557	102	9.80392	10404	1061208	10.0995
48	20.8333	2304	110592	6.9282	103	9.70874	10609	1092727	10.1489
49	20.4082	2401	117649	7.0000	104	9.61538	10816	1124864	10.1980
50	20.0000	2500	125000	7.0711	**105**	9.52381	11025	1157625	10.2470
51	19.6078	2601	132651	7.1414	106	9.43396	11236	1191016	10.2956
52	19.2308	2704	140608	7.2111	107	9.34579	11449	1225043	10.3441
53	18.8679	2809	148877	7.2801	108	9.25926	11664	1259712	10.3923
54	18.5185	2916	157464	7.3485	109	9.17431	11881	1295029	10.4403
55	18.1818	3025	166375	7.4162	**110**	9.09091	12100	1331000	10.4881
56	17.8571	3136	175616	7.4833	111	9.00901	12321	1367631	10.5357
57	17.5439	3249	185193	7.5498	112	8.92857	12544	1404928	10.5830
58	17.2414	3364	195112	7.6158	113	8.84956	12769	1442897	10.6301
59	16.9492	3481	205379	7.6811	114	8.77193	12996	1481544	10.6771
60	16.6667	3600	216000	7.7460	**115**	8.69565	13225	1520875	10.7238
61	16.3934	3721	226981	7.8102	116	8.62069	13456	1560896	10.7703
62	16.1290	3844	238328	7.8740	117	8.54701	13689	1601613	10.8167
63	15.8730	3969	250047	7.9373	118	8.47458	13924	1643032	10.8628
64	15.6250	4096	262144	8.0000	119	8.40336	14161	1685159	10.9087

VALUES OF RECIPROCALS, SQUARES, CUBES, SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
120	8.33333	14400	1728000	10.9545	**175**	5.71429	30625	5359375	13.2288
121	8.26446	14641	1771561	11.0000	176	5.68182	30976	5451776	13.2665
122	8.19672	14884	1815848	11.0454	177	5.64972	31329	5545233	13.3041
123	8.13008	15129	1860867	11.0905	178	5.61798	31684	5639752	13.3417
124	8.06452	15376	1906624	11.1355	179	5.58659	32041	5735339	13.3791
125	8.00000	15625	1953125	11.1803	**180**	5.55556	32400	5832000	13.4164
126	7.93651	15876	2000376	11.2250	181	5.52486	32761	5929741	13.4536
127	7.87402	16129	2048383	11.2694	182	5.49451	33124	6028568	13.4907
128	7.81250	16384	2097152	11.3137	183	5.46448	33489	6128487	13.5277
129	7.75194	16641	2146689	11.3578	184	5.43478	33856	6229504	13.5647
130	7.69231	16900	2197000	11.4018	**185**	5.40541	34225	6331625	13.6015
131	7.63359	17161	2248091	11.4455	186	5.37634	34596	6434856	13.6382
132	7.57576	17424	2299968	11.4891	187	5.34759	34969	6539203	13.6748
133	7.51880	17689	2352637	11.5326	188	5.31915	35344	6644672	13.7113
134	7.46269	17956	2406104	11.5758	189	5.29101	35721	6751269	13.7477
135	7.40741	18225	2460375	11.6190	**190**	5.26316	36100	6859000	13.7840
136	7.35294	18496	2515456	11.6619	191	5.23560	36481	6967871	13.8203
137	7.29927	18769	2571353	11.7047	192	5.20833	36864	7077888	13.8564
138	7.24638	19044	2628072	11.7473	193	5.18135	37249	7189057	13.8924
139	7.19424	19321	2685619	11.7898	194	5.15464	37636	7301384	13.9284
140	7.14286	19600	2744000	11.8322	**195**	5.12821	38025	7414875	13.9642
141	7.09220	19881	2803221	11.8743	196	5.10204	38416	7529536	14.0000
142	7.04225	20164	2863288	11.9164	197	5.07614	38809	7645373	14.0357
143	6.99301	20449	2924207	11.9583	198	5.05051	39204	7762392	14.0712
144	6.94444	20736	2985984	12.0000	199	5.02513	39601	7880599	14.1067
145	6.89655	21025	3048625	12.0416	**200**	5.00000	40000	8000000	14.1421
146	6.84932	21316	3112136	12.0830	201	4.97512	40401	8120601	14.1774
147	6.80272	21609	3176523	12.1244	202	4.95050	40804	8242408	14.2127
148	6.75676	21904	3241792	12.1655	203	4.92611	41209	8365427	14.2478
149	6.71141	22201	3307949	12.2066	204	4.90196	41616	8489664	14.2829
150	6.66667	22500	3375000	12.2474	**205**	4.87805	42025	8615125	14.3178
151	6.62252	22801	3442951	12.2882	206	4.85437	42436	8741816	14.3527
152	6.57895	23104	3511808	12.3288	207	4.83092	42849	8869743	14.3875
153	6.53595	23409	3581577	12.3693	208	4.80769	43264	8998912	14.4222
154	6.49351	23716	3652264	12.4097	209	4.78469	43681	9129329	14.4568
155	6.45161	24025	3723875	12.4499	**210**	4.76190	44100	9261000	14.4914
156	6.41026	24336	3796416	12.4900	211	4.73934	44521	9393931	14.5258
157	6.36943	24649	3869893	12.5300	212	4.71698	44944	9528128	14.5602
158	6.32911	24964	3944312	12.5698	213	4.69484	45369	9663597	14.5945
159	6.28931	25281	4019679	12.6095	214	4.67290	45796	9800344	14.6287
160	6.25000	25600	4096000	12.6491	**215**	4.65116	46225	9938375	14.6629
161	6.21118	25921	4173281	12.6886	216	4.62963	46656	10077696	14.6969
162	6.17284	26244	4251528	12.7279	217	4.60829	47089	10218313	14.7309
163	6.13497	26569	4330747	12.7671	218	4.58716	47524	10360232	14.7648
164	6.09756	26896	4410944	12.8062	219	4.56621	47961	10503459	14.7986
165	6.06061	27225	4492125	12.8452	**220**	4.54545	48400	10648000	14.8324
166	6.02410	27556	4574296	12.8841	221	4.52489	48841	10793861	14.8661
167	5.98802	27889	4657463	12.9228	222	4.50450	49284	10941048	14.8997
168	5.95238	28224	4741632	12.9615	223	4.48430	49729	11089567	14.9332
169	5.91716	28561	4826809	13.0000	224	4.46429	50176	11239424	14.9666
170	5.88235	28900	4913000	13.0384	**225**	4.44444	50625	11390625	15.0000
171	5.84795	29241	5000211	13.0767	226	4.42478	51076	11543176	15.0333
172	5.81395	29584	5088448	13.1149	227	4.40529	51529	11697083	15.0665
173	5.78035	29929	5177717	13.1529	228	4.38596	51984	11852352	15.0997
174	5.74713	30276	5268024	13.1909	229	4.36681	52441	12008989	15.1327

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS, OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
230	4.34783	52900	12167000	15.1658	**285**	3.50877	81225	23149125	16.8819
231	4.32900	53361	12326391	15.1987	286	3.49650	81796	23393656	16.9115
232	4.31034	53824	12487168	15.2315	287	3.48432	82369	23639903	16.9411
233	4.29185	54289	12649337	15.2643	288	3.47222	82944	23887872	16.9706
234	4.27350	54756	12812904	15.2971	289	3.46021	83521	24137569	17.0000
235	4.25532	55225	12977875	15.3297	**290**	3.44828	84100	24389000	17.0294
236	4.23729	55696	13144256	15.3623	291	3.43643	84681	24642171	17.0587
237	4.21941	56169	13312053	15.3948	292	3.42466	85264	24897088	17.0880
238	4.20168	56644	13481272	15.4272	293	3.41297	85849	25153757	17.1172
239	4.18410	57121	13651919	15.4596	294	3.40136	86436	25412184	17.1464
240	4.16667	57600	13824000	15.4919	**295**	3.38983	87025	25672375	17.1756
241	4.14938	58081	13997521	15.5242	296	3.37838	87616	25934336	17.2047
242	4.13223	58564	14172488	15.5563	297	3.36700	88209	26198073	17.2337
243	4.11523	59049	14348907	15.5885	298	3.35570	88804	26463592	17.2627
244	4.09836	59536	14526784	15.6205	299	3.34448	89401	26730899	17.2916
245	4.08163	60025	14706125	15.6525	**300**	3.33333	90000	27000000	17.3205
246	4.06504	60516	14886936	15.6844	301	3.32226	90601	27270901	17.3494
247	4.04858	61009	15069223	15.7162	302	3.31126	91204	27543608	17.3781
248	4.03226	61504	15252992	15.7480	303	3.30033	91809	27818127	17.4069
249	4.01606	62001	15438249	15.7797	304	3.28947	92416	28094464	17.4356
250	4.00000	62500	15625000	15.8114	**305**	3.27869	93025	28372625	17.4642
251	3.98406	63001	15813251	15.8430	306	3.26797	93636	28652616	17.4929
252	3.96825	63504	16003008	15.8745	307	3.25733	94249	28934443	17.5214
253	3.95257	64009	16194277	15.9060	308	3.24675	94864	29218112	17.5499
254	3.93701	64516	16387064	15.9374	309	3.23625	95481	29503629	17.5784
255	3.92157	65025	16581375	15.9687	**310**	3.22581	96100	29791000	17.6068
256	3.90625	65536	16777216	16.0000	311	3.21543	96721	30080231	17.6352
257	3.89105	66049	16974593	16.0312	312	3.20513	97344	30371328	17.6635
258	3.87597	66564	17173512	16.0624	313	3.19489	97969	30664297	17.6918
259	3.86100	67081	17373979	16.0935	314	3.18471	98596	30959144	17.7200
260	3.84615	67600	17576000	16.1245	**315**	3.17460	99225	31255875	17.7482
261	3.83142	68121	17779581	16.1555	316	3.16456	99856	31554496	17.7764
262	3.81679	68644	17984728	16.1864	317	3.15457	100489	31855013	17.8045
263	3.80228	69169	18191447	16.2173	318	3.14465	101124	32157432	17.8326
264	3.78788	69696	18399744	16.2481	319	3.13480	101761	32461759	17.8606
265	3.77358	70225	18609625	16.2788	**320**	3.12500	102400	32768000	17.8885
266	3.75940	70756	18821096	16.3095	321	3.11526	103041	33076161	17.9165
267	3.74532	71289	19034163	16.3401	322	3.10559	103684	33386248	17.9444
268	3.73134	71824	19248832	16.3707	323	3.09598	104329	33698267	17.9722
269	3.71747	72361	19465109	16.4012	324	3.08642	104976	34012224	18.0000
270	3.70370	72900	19683000	16.4317	**325**	3.07692	105625	34328125	18.0278
271	3.69004	73441	19902511	16.4621	326	3.06748	106276	34645976	18.0555
272	3.67647	73984	20123648	16.4924	327	3.05810	106929	34965783	18.0831
273	3.66300	74529	20346417	16.5227	328	3.04878	107584	35287552	18.1108
274	3.64964	75076	20570824	16.5529	329	3.03951	108241	35611289	18.1384
275	3.63636	75625	20796875	16.5831	**330**	3.03030	108900	35937000	18.1659
276	3.62319	76176	21024576	16.6132	331	3.02115	109561	36264691	18.1934
277	3.61011	76729	21253933	16.6433	332	3.01205	110224	36594368	18.2209
278	3.59712	77284	21484952	16.6733	333	3.00300	110889	36926037	18.2483
279	3.58423	77841	21717639	16.7033	334	2.99401	111556	37259704	18.2757
280	3.57143	78400	21952000	16.7332	**335**	2.98507	112225	37595375	18.3030
281	3.55872	78961	22188041	16.7631	336	2.97619	112896	37933056	18.3303
282	3.54610	79524	22425768	16.7929	337	2.96736	113569	38272753	18.3576
283	3.53357	80089	22665187	16.8226	338	2.95858	114244	38614472	18.3848
284	3.52113	80656	22906304	16.8523	339	2.94985	114921	38958219	18.4120

Table 8 (*continued*).

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
340	2.94118	115600	39304000	18.4391	**395**	2.53165	156025	61629875	19.8746
341	2.93255	116281	39651821	18.4662	396	2.52525	156816	62099136	19.8997
342	2.92398	116964	40001688	18.4932	397	2.51889	157609	62570773	19.9249
343	2.91545	117649	40353607	18.5203	398	2.51256	158404	63044792	19.9499
344	2.90698	118336	40707584	18.5472	399	2.50627	159201	63521199	19.9750
345	2.89855	119025	41063625	18.5742	**400**	2.50000	160000	64000000	20.0000
346	2.89017	119716	41421736	18.6011	401	2.49377	160801	64481201	20.0250
347	2.88184	120409	41781923	18.6279	402	2.48756	161604	64964808	20.0499
348	2.87356	121104	42144192	18.6548	403	2.48139	162409	65450827	20.0749
349	2.86533	121801	42508549	18.6815	404	2.47525	163216	65939264	20.0998
350	2.85714	122500	42875000	18.7083	**405**	2.46914	164025	66430125	20.1246
351	2.84900	123201	43243551	18.7350	406	2.46305	164836	66923416	20.1494
352	2.84091	123904	43614208	18.7617	407	2.45700	165649	67419143	20.1742
353	2.83286	124609	43986977	18.7883	408	2.45098	166464	67917312	20.1990
354	2.82486	125316	44361864	18.8149	409	2.44499	167281	68417929	20.2237
355	2.81690	126025	44738875	18.8414	**410**	2.43902	168100	68921000	20.2485
356	2.80899	126736	45118016	18.8680	411	2.43309	168921	69426531	20.2731
357	2.80112	127449	45499293	18.8944	412	2.42718	169744	69934528	20.2978
358	2.79330	128164	45882712	18.9209	413	2.42131	170569	70444997	20.3224
359	2.78552	128881	46268279	18.9473	414	2.41546	171396	70957944	20.3470
360	2.77778	129600	46656000	18.9737	**415**	2.40964	172225	71473375	20.3715
361	2.77008	130321	47045881	19.0000	416	2.40385	173056	71991296	20.3961
362	2.76243	131044	47437928	19.0263	417	2.39808	173889	72511713	20.4206
363	2.75482	131769	47832147	19.0526	418	2.39234	174724	73034632	20.4450
364	2.74725	132496	48228544	19.0788	419	2.38663	175561	73560059	20.4695
365	2.73973	133225	48627125	19.1050	**420**	2.38095	176400	74088000	20.4939
366	2.73224	133956	49027896	19.1311	421	2.37530	177241	74618461	20.5183
367	2.72480	134689	49430863	19.1572	422	2.36967	178084	75151448	20.5426
368	2.71739	135424	49836032	19.1833	423	2.36407	178929	75686967	20.5670
369	2.71003	136161	50243409	19.2094	424	2.35849	179776	76225024	20.5913
370	2.70270	136900	50653000	19.2354	**425**	2.35294	180625	76765625	20.6155
371	2.69542	137641	51064811	19.2614	426	2.34742	181476	77308776	20.6398
372	2.68817	138384	51478848	19.2873	427	2.34192	182329	77854483	20.6640
373	2.68097	139129	51895117	19.3132	428	2.33645	183184	78402752	20.6882
374	2.67380	139876	52313624	19.3391	429	2.33100	184041	78953589	20.7123
375	2.66667	140625	52734375	19.3649	**430**	2.32558	184900	79507000	20.7364
376	2.65957	141376	53157376	19.3907	431	2.32019	185761	80062991	20.7605
377	2.65252	142129	53582633	19.4165	432	2.31481	186624	80621568	20.7846
378	2.64550	142884	54010152	19.4422	433	2.30947	187489	81182737	20.8087
379	2.63852	143641	54439939	19.4679	434	2.30415	188356	81746504	20.8327
380	2.63158	144400	54872000	19.4936	**435**	2.29885	189225	82312875	20.8567
381	2.62467	145161	55306341	19.5192	436	2.29358	190096	82881856	20.8806
382	2.61780	145924	55742968	19.5448	437	2.28833	190969	83453453	20.9045
383	2.61097	146689	56181887	19.5704	438	2.28311	191844	84027672	20.9284
384	2.60417	147456	56623104	19.5959	439	2.27790	192721	84604519	20.9523
385	2.59740	148225	57066625	19.6214	**440**	2.27273	193600	85184000	20.9762
386	2.59067	148996	57512456	19.6469	441	2.26757	194481	85766121	21.0000
387	2.58398	149769	57960603	19.6723	442	2.26244	195364	86350888	21.0238
388	2.57732	150544	58411072	19.6977	443	2.25734	196249	86938307	21.0476
389	2.57069	151321	58863869	19.7231	444	2.25225	197136	87528384	21.0713
390	2.56410	152100	59319000	19.7484	**445**	2.24719	198025	88121125	21.0950
391	2.55754	152881	59776471	19.7737	446	2.24215	198916	88716536	21.1187
392	2.55102	153664	60236288	19.7990	447	2.23714	199809	89314623	21.1424
393	2.54453	154449	60698457	19.8242	448	2.23214	200704	89915392	21.1660
394	2.53807	155236	61162984	19.8494	449	2.22717	201601	90518849	21.1896

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
450	2.22222	202500	91125000	21.2132	**505**	1.98020	255025	128787625	22.4722
451	2.21729	203401	91733851	21.2368	506	1.97628	256036	129554216	22.4944
452	2.21239	204304	92345408	21.2603	507	1.97239	257049	130323843	22.5167
453	2.20751	205209	92959677	21.2838	508	1.96850	258064	131096512	22.5389
454	2.20264	206116	93576664	21.3073	509	1.96464	259081	131872229	22.5610
455	2.19780	207025	94196375	21.3307	**510**	1.96078	260100	132651000	22.5832
456	2.19298	207936	94818816	21.3542	511	1.95695	261121	133432831	22.6053
457	2.18818	208849	95443993	21.3776	512	1.95312	262144	134217728	22.6274
458	2.18341	209764	96071912	21.4009	513	1.94932	263169	135005697	22.6495
459	2.17865	210681	96702579	21.4243	514	1.94553	264196	135796744	22.6716
460	2.17391	211600	97336000	21.4476	**515**	1.94175	265225	136590875	22.6936
461	2.16920	212521	97972181	21.4709	516	1.93798	266256	137388096	22.7156
462	2.16450	213444	98611128	21.4942	517	1.93424	267289	138188413	22.7376
463	2.15983	214369	99252847	21.5174	518	1.93050	268324	138991832	22.7596
464	2.15517	215296	99897344	21.5407	519	1.92678	269361	139798359	22.7816
465	2.15054	216225	100544625	21.5639	**520**	1.92308	270400	140608000	22.8035
466	2.14592	217156	101194696	21.5870	521	1.91939	271441	141420761	22.8254
467	2.14133	218089	101847563	21.6102	522	1.91571	272484	142236648	22.8473
468	2.13675	219024	102503232	21.6333	523	1.91205	273529	143055667	22.8692
469	2.13220	219961	103161709	21.6564	524	1.90840	274576	143877824	22.8910
470	2.12766	220900	103823000	21.6795	**525**	1.90476	275625	144703125	22.9129
471	2.12314	221841	104487111	21.7025	526	1.90114	276676	145531576	22.9347
472	2.11864	222784	105154048	21.7256	527	1.89753	277729	146363183	22.9565
473	2.11416	223729	105823817	21.7486	528	1.89394	278784	147197952	22.9783
474	2.10970	224676	106496424	21.7715	529	1.89036	279841	148035889	23.0000
475	2.10526	225625	107171875	21.7945	**530**	1.88679	280900	148877000	23.0217
476	2.10084	226576	107850176	21.8174	531	1.88324	281961	149721291	23.0434
477	2.09644	227529	108531333	21.8403	532	1.87970	283024	150568768	23.0651
478	2.09205	228484	109215352	21.8632	533	1.87617	284089	151419437	23.0868
479	2.08768	229441	109902239	21.8861	534	1.87266	285156	152273304	23.1084
480	2.08333	230400	110592000	21.9089	**535**	1.86916	286225	153130375	23.1301
481	2.07900	231361	111284641	21.9317	536	1.86567	287296	153990656	23.1517
482	2.07469	232324	111980168	21.9545	537	1.86220	288369	154854153	23.1733
483	2.07039	233289	112678587	21.9773	538	1.85874	289444	155720872	23.1948
484	2.06612	234256	113379904	22.0000	539	1.85529	290521	156590819	23.2164
485	2.06186	235225	114084125	22.0227	**540**	1.85185	291600	157464000	23.2379
486	2.05761	236196	114791256	22.0454	541	1.84843	292681	158340421	23.2594
487	2.05339	237169	115501303	22.0681	542	1.84502	293764	159220088	23.2809
488	2.04918	238144	116214272	22.0907	543	1.84162	294849	160103007	23.3024
489	2.04499	239121	116930169	22.1133	544	1.83824	295936	160989184	23.3238
490	2.04082	240100	117649000	22.1359	**545**	1.83486	297025	161878625	23.3452
491	2.03666	241081	118370771	22.1585	546	1.83150	298116	162771336	23.3666
492	2.03252	242064	119095488	22.1811	547	1.82815	299209	163667323	23.3880
493	2.02840	243049	119823157	22.2036	548	1.82482	300304	164566592	23.4094
494	2.02429	244036	120553784	22.2261	549	1.82149	301401	165469149	23.4307
495	2.02020	245025	121287375	22.2486	**550**	1.81818	302500	166375000	23.4521
496	2.01613	246016	122023936	22.2711	551	1.81488	303601	167284151	23.4734
497	2.01207	247009	122763473	22.2935	552	1.81159	304704	168196608	23.4947
498	2.00803	248004	123505992	22.3159	553	1.80832	305809	169112377	23.5160
499	2.00401	249001	124251499	22.3383	554	1.80505	306916	170031464	23.5372
500	2.00000	250000	125000000	22.3607	**555**	1.80180	308025	170953875	23.5584
501	1.99601	251001	125751501	22.3830	556	1.79856	309136	171879616	23.5797
502	1.99203	252004	126506008	22.4054	557	1.79533	310249	172808693	23.6008
503	1.98807	253009	127263527	22.4277	558	1.79211	311364	173741112	23.6220
504	1.98413	254016	128024064	22.4499	559	1.78891	312481	174676879	23.6432

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	1000.1/n	n²	n³	√n	n	1000.1/n	n²	n³	√n
560	1.78571	313600	175616000	23.6643	**615**	1.62602	378225	232608375	24.7992
561	1.78253	314721	176558481	23.6854	616	1.62338	379456	233744896	24.8193
562	1.77936	315844	177504328	23.7065	617	1.62075	380689	234885113	24.8395
563	1.77620	316969	178453547	23.7276	618	1.61812	381924	236029032	24.8596
564	1.77305	318096	179406144	23.7487	619	1.61551	383161	237176659	24.8797
565	1.76991	319225	180362125	23.7697	**620**	1.61290	384400	238328000	24.8998
566	1.76678	320356	181321496	23.7908	621	1.61031	385641	239483061	24.9199
567	1.76367	321489	182284263	23.8118	622	1.60772	386884	240641848	24.9399
568	1.76056	322624	183250432	23.8328	623	1.60514	388129	241804367	24.9600
569	1.75747	323761	184220009	23.8537	624	1.60256	389376	242970624	24.9800
570	1.75439	324900	185193000	23.8747	**625**	1.60000	390625	244140625	25.0000
571	1.75131	326041	186169411	23.8956	626	1.59744	391876	245314376	25.0200
572	1.74825	327184	187149248	23.9165	627	1.59490	393129	246491883	25.0400
573	1.74520	328329	188132517	23.9374	628	1.59236	394384	247673152	25.0599
574	1.74216	329476	189119224	23.9583	629	1.58983	395641	248858189	25.0799
575	1.73913	330625	190109375	23.9792	**630**	1.58730	396900	250047000	25.0998
576	1.73611	331776	191102976	24.0000	631	1.58479	398161	251239591	25.1197
577	1.73310	332929	192100033	24.0208	632	1.58228	399424	252435968	25.1396
578	1.73010	334084	193100552	24.0416	633	1.57978	400689	253636137	25.1595
579	1.72712	335241	194104539	24.0624	634	1.57729	401956	254840104	25.1794
580	1.72414	336400	195112000	24.0832	**635**	1.57480	403225	256047875	25.1992
581	1.72117	337561	196122941	24.1039	636	1.57233	404496	257259456	25.2190
582	1.71821	338724	197137368	24.1247	637	1.56986	405769	258474853	25.2389
583	1.71527	339889	198155287	24.1454	638	1.56740	407044	259694072	25.2587
584	1.71233	341056	199176704	24.1661	639	1.56495	408321	260917119	25.2784
585	1.70940	342225	200201625	24.1868	**640**	1.56250	409600	262144000	25.2982
586	1.70648	343396	201230056	24.2074	641	1.56006	410881	263374721	25.3180
587	1.70358	344569	202262003	24.2281	642	1.55763	412164	264609288	25.3377
588	1.70068	345744	203297472	24.2487	643	1.55521	413449	265847707	25.3574
589	1.69779	346921	204336469	24.2693	644	1.55280	414736	267089984	25.3772
590	1.69492	348100	205379000	24.2899	**645**	1.55039	416025	268336125	25.3969
591	1.69205	349281	206425071	24.3105	646	1.54799	417316	269586136	25.4165
592	1.68919	350464	207474688	24.3311	647	1.54560	418609	270840023	25.4362
593	1.68634	351649	208527857	24.3516	648	1.54321	419904	272097792	25.4558
594	1.68350	352836	209584584	24.3721	649	1.54083	421201	273359449	25.4755
595	1.68067	354025	210644875	24.3926	**650**	1.53846	422500	274625000	25.4951
596	1.67785	355216	211708736	24.4131	651	1.53610	423801	275894451	25.5147
597	1.67504	356409	212776173	24.4336	652	1.53374	425104	277167808	25.5343
598	1.67224	357604	213847192	24.4540	653	1.53139	426409	278445077	25.5539
599	1.66945	358801	214921799	24.4745	654	1.52905	427716	279726264	25.5734
600	1.66667	360000	216000000	24.4949	**655**	1.52672	429025	281011375	25.5930
601	1.66389	361201	217081801	24.5153	656	1.52439	430336	282300416	25.6125
602	1.66113	362404	218167208	24.5357	657	1.52207	431649	283593393	25.6320
603	1.65837	363609	219256227	24.5561	658	1.51976	432964	284890312	25.6515
604	1.65563	364816	220348864	24.5764	659	1.51745	434281	286191179	25.6710
605	1.65289	366025	221445125	24.5967	**660**	1.51515	435600	287496000	25.6905
606	1.65017	367236	222545016	24.6171	661	1.51286	436921	288804781	25.7099
607	1.64745	368449	223648543	24.6374	662	1.51057	438244	290117528	25.7294
608	1.64474	369664	224755712	24.6577	663	1.50830	439569	291434247	25.7488
609	1.64204	370881	225866529	24.6779	664	1.50602	440896	292754944	25.7682
610	1.63934	372100	226981000	24.6982	**665**	1.50376	442225	294079625	25.7876
611	1.63666	373321	228099131	24.7184	666	1.50150	443556	295408296	25.8070
612	1.63399	374544	229220928	24.7386	667	1.49925	444889	296740963	25.8263
613	1.63132	375769	230346397	24.7588	668	1.49701	446224	298077632	25.8457
614	1.62866	376996	231475544	24.7790	669	1.49477	447561	299418309	25.8650

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
670	1.49254	448900	300763000	25.8844	**725**	1.37931	525625	381078125	26.9258
671	1.49031	450241	302111711	25.9037	726	1.37741	527076	382657176	26.9444
672	1.48810	451584	303464448	25.9230	727	1.37552	528529	384240583	26.9629
673	1.48588	452929	304821217	25.9422	728	1.37363	529984	385828352	26.9815
674	1.48368	454276	306182024	25.9615	729	1.37174	531441	387420489	27.0000
675	1.48148	455625	307546875	25.9808	**730**	1.36986	532900	389017000	27.0185
676	1.47929	456976	308915776	26.0000	731	1.36799	534361	390617891	27.0370
677	1.47710	458329	310288733	26.0192	732	1.36612	535824	392223168	27.0555
678	1.47493	459684	311665752	26.0384	733	1.36426	537289	393832837	27.0740
679	1.47275	461041	313046839	26.0576	734	1.36240	538756	395446904	27.0924
680	1.47059	462400	314432000	26.0768	**735**	1.36054	540225	397065375	27.1109
681	1.46843	463761	315821241	26.0960	736	1.35870	541696	398688256	27.1293
682	1.46628	465124	317214568	26.1151	737	1.35685	543169	400315553	27.1477
683	1.46413	466489	318611987	26.1343	738	1.35501	544644	401947272	27.1662
684	1.46199	467856	320013504	26.1534	739	1.35318	546121	403583419	27.1846
685	1.45985	469225	321419125	26.1725	**740**	1.35135	547600	405224000	27.2029
686	1.45773	470596	322828856	26.1916	741	1.34953	549081	406869021	27.2213
687	1.45560	471969	324242703	26.2107	742	1.34771	550564	408518488	27.2397
688	1.45349	473344	325660672	26.2298	743	1.34590	552049	410172407	27.2580
689	1.45138	474721	327082769	26.2488	744	1.34409	553536	411830784	27.2764
690	1.44928	476100	328509000	26.2679	**745**	1.34228	555025	413493625	27.2947
691	1.44718	477481	329939371	26.2869	746	1.34048	556516	415160936	27.3130
692	1.44509	478864	331373888	26.3059	747	1.33869	558009	416832723	27.3313
693	1.44300	480249	332812557	26.3249	748	1.33690	559504	418508992	27.3496
694	1.44092	481636	334255384	26.3439	749	1.33511	561001	420189749	27.3679
695	1.43885	483025	335702375	26.3629	**750**	1.33333	562500	421875000	27.3861
696	1.43678	484416	337153536	26.3818	751	1.33156	564001	423564751	27.4044
697	1.43472	485809	338608873	26.4008	752	1.32979	565504	425259008	27.4226
698	1.43266	487204	340068392	26.4197	753	1.32802	567009	426957777	27.4408
699	1.43062	488601	341532099	26.4386	754	1.32626	568516	428661064	27.4591
700	1.42857	490000	343000000	26.4575	**755**	1.32450	570025	430368875	27.4773
701	1.42653	491401	344472101	26.4764	756	1.32275	571536	432081216	27.4955
702	1.42450	492804	345948408	26.4953	757	1.32100	573049	433798093	27.5136
703	1.42248	494209	347428927	26.5141	758	1.31926	574564	435519512	27.5318
704	1.42045	495616	348913664	26.5330	759	1.31752	576081	437245479	27.5500
705	1.41844	497025	350402625	26.5518	**760**	1.31579	577600	438976000	27.5681
706	1.41643	498436	351895816	26.5707	761	1.31406	579121	440711081	27.5862
707	1.41443	499849	353393243	26.5895	762	1.31234	580644	442450728	27.6043
708	1.41243	501264	354894912	26.6083	763	1.31062	582169	444194947	27.6225
709	1.41044	502681	356400829	26.6271	764	1.30890	583696	445943744	27.6405
710	1.40845	504100	357911000	26.6458	**765**	1.30719	585225	447697125	27.6586
711	1.40647	505521	359425431	26.6646	766	1.30548	586756	449455096	27.6767
712	1.40449	506944	360944128	26.6833	767	1.30378	588289	451217663	27.6948
713	1.40252	508369	362467097	26.7021	768	1.30208	589824	452984832	27.7128
714	1.40056	509796	363994344	26.7208	769	1.30039	591361	454756609	27.7308
715	1.39860	511225	365525875	26.7395	**770**	1.29870	592900	456533000	27.7489
716	1.39665	512656	367061696	26.7582	771	1.29702	594441	458314011	27.7669
717	1.39470	514089	368601813	26.7769	772	1.29534	595984	460099648	27.7849
718	1.39276	515524	370146232	26.7955	773	1.29366	597529	461889917	27.8029
719	1.39082	516961	371694959	26.8142	774	1.29199	599076	463684824	27.8209
720	1.38889	518400	373248000	26.8328	**775**	1.29032	600625	465484375	27.8388
721	1.38696	519841	374805361	26.8514	776	1.28866	602176	467288576	27.8568
722	1.38504	521284	376367048	26.8701	777	1.28700	603729	469097433	27.8747
723	1.38313	522729	377933067	26.8887	778	1.28535	605284	470910952	27.8927
724	1.38122	524176	379503424	26.9072	779	1.28370	606841	472729139	27.9106

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
780	1.28205	608400	474552000	27.9285	**835**	1.19760	697225	582182875	28.8964
781	1.28041	609961	476379541	27.9464	836	1.19617	698896	584277056	28.9137
782	1.27877	611524	478211768	27.9643	837	1.19474	700569	586376253	28.9310
783	1.27714	613089	480048687	27.9821	838	1.19332	702244	588480472	28.9482
784	1.27551	614656	481890304	28.0000	839	1.19190	703921	590589719	28.9655
785	1.27389	616225	483736625	28.0179	**840**	1.19048	705600	592704000	28.9828
786	1.27226	617796	485587656	28.0357	841	1.18906	707281	594823321	29.0000
787	1.27065	619369	487443403	28.0535	842	1.18765	708964	596947688	29.0172
788	1.26904	620944	489303872	28.0713	843	1.18624	710649	599077107	29.0345
789	1.26743	622521	491169069	28.0891	844	1.18483	712336	601211584	29.0517
790	1.26582	624100	493039000	28.1069	**845**	1.18343	714025	603351125	29.0689
791	1.26422	625681	494913671	28.1247	846	1.18203	715716	605495736	29.0861
792	1.26263	627264	496793088	28.1425	847	1.18064	717409	607645423	29.1033
793	1.26103	628849	498677257	28.1603	848	1.17925	719104	609800192	29.1204
794	1.25945	630436	500566184	28.1780	849	1.17786	720801	611960049	29.1376
795	1.25786	632025	502459875	28.1957	**850**	1.17647	722500	614125000	29.1548
796	1.25628	633616	504358336	28.2135	851	1.17509	724201	616295051	29.1719
797	1.25471	635209	506261573	28.2312	852	1.17371	725904	618470208	29.1890
798	1.25313	636804	508169592	28.2489	853	1.17233	727609	620650477	29.2062
799	1.25156	638401	510082399	28.2666	854	1.17096	729316	622835864	29.2233
800	1.25000	640000	512000000	28.2843	**855**	1.16959	731025	625026375	29.2404
801	1.24844	641601	513922401	28.3019	856	1.16822	732736	627222016	29.2575
802	1.24688	643204	515849608	28.3196	857	1.16686	734449	629422793	29.2746
803	1.24533	644809	517781627	28.3373	858	1.16550	736164	631628712	29.2916
804	1.24378	646416	519718464	28.3549	859	1.16414	737881	633839779	29.3087
805	1.24224	648025	521660125	28.3725	**860**	1.16279	739600	636056000	29.3258
806	1.24069	649636	523606616	28.3901	861	1.16144	741321	638277381	29.3428
807	1.23916	651249	525557943	28.4077	862	1.16009	743044	640503928	29.3598
808	1.23762	652864	527514112	28.4253	863	1.15875	744769	642735647	29.3769
809	1.23609	654481	529475129	28.4429	864	1.15741	746496	644972544	29.3939
810	1.23457	656100	531441000	28.4605	**865**	1.15607	748225	647214625	29.4109
811	1.23305	657721	533411731	28.4781	866	1.15473	749956	649461896	29.4279
812	1.23153	659344	535387328	28.4956	867	1.15340	751689	651714363	29.4449
813	1.23001	660969	537367797	28.5132	868	1.15207	753424	653972032	29.4618
814	1.22850	662596	539353144	28.5307	869	1.15075	755161	656234909	29.4788
815	1.22699	664225	541343375	28.5482	**870**	1.14943	756900	658503000	29.4958
816	1.22549	665856	543338496	28.5657	871	1.14811	758641	660776311	29.5127
817	1.22399	667489	545338513	28.5832	872	1.14679	760384	663054848	29.5296
818	1.22249	669124	547343432	28.6007	873	1.14548	762129	665338617	29.5466
819	1.22100	670761	549353259	28.6182	874	1.14416	763876	667627624	29.5635
820	1.21951	672400	551368000	28.6356	**875**	1.14286	765625	669921875	29.5804
821	1.21803	674041	553387661	28.6531	876	1.14155	767376	672221376	29.5973
822	1.21655	675684	555412248	28.6705	877	1.14025	769129	674526133	29.6142
823	1.21507	677329	557441767	28.6880	878	1.13895	770884	676836152	29.6311
824	1.21359	678976	559476224	28.7054	879	1.13766	772641	679151439	29.6479
825	1.21212	680625	561515625	28.7228	**880**	1.13636	774400	681472000	29.6648
826	1.21065	682276	563559976	28.7402	881	1.13507	776161	683797841	29.6816
827	1.20919	683929	565609283	28.7576	882	1.13379	777924	686128968	29.6985
828	1.20773	685584	567663552	28.7750	883	1.13250	779689	688465387	29.7153
829	1.20627	687241	569722789	28.7924	884	1.13122	781456	690807104	29.7321
830	1.20482	688900	571787000	28.8097	**885**	1.12994	783225	693154125	29.7489
831	1.20337	690561	573856191	28.8271	886	1.12867	784996	695506456	29.7658
832	1.20192	692224	575930368	28.8444	887	1.12740	786769	697864103	29.7825
833	1.20048	693889	578009537	28.8617	888	1.12613	788544	700227072	29.7993
834	1.19904	695556	580093704	28.8791	889	1.12486	790321	702595369	29.8161

VALUES OF RECIPROCALS, SQUARES, CUBES, AND SQUARE ROOTS OF NATURAL NUMBERS.

n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$	n	$1000.\frac{1}{n}$	n^2	n^3	$\sqrt{n}$
890	1.12360	792100	704969000	29.8329	**945**	1.05820	893025	843908625	30.7409
891	1.12233	793881	707347971	29.8496	946	1.05708	894916	846590536	30.7571
892	1.12108	795664	709732288	29.8664	947	1.05597	896809	849278123	30.7734
893	1.11982	797449	712121957	29.8831	948	1.05485	898704	851971392	30.7896
894	1.11857	799236	714516984	29.8998	949	1.05374	900601	854670349	30.8058
895	1.11732	801025	716917375	29.9166	**950**	1.05263	902500	857375000	30.8221
896	1.11607	802816	719323136	29.9333	951	1.05152	904401	860085351	30.8383
897	1.11483	804609	721734273	29.9500	952	1.05042	906304	862801408	30.8545
898	1.11359	806404	724150792	29.9666	953	1.04932	908209	865523177	30.8707
899	1.11235	808201	726572699	29.9833	954	1.04822	910116	868250664	30.8869
900	1.11111	810000	729000000	30.0000	**955**	1.04712	912025	870983875	30.9031
901	1.10988	811801	731432701	30.0167	956	1.04603	913936	873722816	30.9192
902	1.10865	813604	733870808	30.0333	957	1.04493	915849	876467493	30.9354
903	1.10742	815409	736314327	30.0500	958	1.04384	917764	879217912	30.9516
904	1.10619	817216	738763264	30.0666	959	1.04275	919681	881974079	30.9677
905	1.10497	819025	741217625	30.0832	**960**	1.04167	921600	884736000	30.9839
906	1.10375	820836	743677416	30.0998	961	1.04058	923521	887503681	31.0000
907	1.10254	822649	746142643	30.1164	962	1.03950	925444	890277128	31.0161
908	1.10132	824464	748613312	30.1330	963	1.03842	927369	893056347	31.0322
909	1.10011	826281	751089429	30.1496	964	1.03734	929296	895841344	31.0483
910	1.09890	828100	753571000	30.1662	**965**	1.03627	931225	898632125	31.0644
911	1.09769	829921	756058031	30.1828	966	1.03520	933156	901428696	31.0805
912	1.09649	831744	758550528	30.1993	967	1.03413	935089	904231063	31.0966
913	1.09529	833569	761048497	30.2159	968	1.03306	937024	907039232	31.1127
914	1.09409	835396	763551944	30.2324	969	1.03199	938961	909853209	31.1288
915	1.09290	837225	766060875	30.2490	**970**	1.03093	940900	912673000	31.1448
916	1.09170	839056	768575296	30.2655	971	1.02987	942841	915498611	31.1609
917	1.09051	840889	771095213	30.2820	972	1.02881	944784	918330048	31.1769
918	1.08932	842724	773620632	30.2985	973	1.02775	946729	921167317	31.1929
919	1.08814	844561	776151559	30.3150	974	1.02669	948676	924010424	31.2090
920	1.08696	846400	778688000	30.3315	**975**	1.02564	950625	926859375	31.2250
921	1.08578	848241	781229961	30.3480	976	1.02459	952576	929714176	31.2410
922	1.08460	850084	783777448	30.3645	977	1.02354	954529	932574833	31.2570
923	1.08342	851929	786330467	30.3809	978	1.02249	956484	935441352	31.2730
924	1.08225	853776	788889024	30.3974	979	1.02145	958441	938313739	31.2890
925	1.08108	855625	791453125	30.4138	**980**	1.02041	960400	941192000	31.3050
926	1.07991	857476	794022776	30.4302	981	1.01937	962361	944076141	31.3209
927	1.07875	859329	796597983	30.4467	982	1.01833	964324	946966168	31.3369
928	1.07759	861184	799178752	30.4631	983	1.01729	966289	949862087	31.3528
929	1.07643	863041	801765089	30.4795	984	1.01626	968256	952763904	31.3688
930	1.07527	864900	804357000	30.4959	**985**	1.01523	970225	955671625	31.3847
931	1.07411	866761	806954491	30.5123	986	1.01420	972196	958585256	31.4006
932	1.07296	868624	809557568	30.5287	987	1.01317	974169	961504803	31.4166
933	1.07181	870489	812166237	30.5450	988	1.01215	976144	964430272	31.4325
934	1.07066	872356	814780504	30.5614	989	1.01112	978121	967361669	31.4484
935	1.06952	874225	817400375	30.5778	**990**	1.01010	980100	970299000	31.4643
936	1.06838	876096	820025856	30.5941	991	1.00908	982081	973242271	31.4802
937	1.06724	877969	822656953	30.6105	992	1.00806	984064	976191488	31.4960
938	1.06610	879844	825293672	30.6268	993	1.00705	986049	979146657	31.5119
939	1.06496	881721	827936019	30.6431	994	1.00604	988036	982107784	31.5278
940	1.06383	883600	830584000	30.6594	**995**	1.00503	990025	985074875	31.5436
941	1.06270	885481	833237621	30.6757	996	1.00402	992016	988047936	31.5595
942	1.06157	887364	835896888	30.6920	997	1.00301	994009	991026973	31.5753
943	1.06045	889249	838561807	30.7083	998	1.00200	996004	994011992	31.5911
944	1.05932	891136	841232384	30.7246	999	1.00100	998001	997002999	31.6070

TABLE 9.

LOGARITHMS.

N.	0	1	2	3	4	5	6	7	8	9	10
100	0000	0004	0009	0013	0017	0022	0026	0030	0035	0039	0043
101	0043	0048	0052	0056	0060	0065	0069	0073	0077	0082	0086
102	0086	0090	0095	0099	0103	0107	0111	0116	0120	0124	0128
103	0128	0133	0137	0141	0145	0149	0154	0158	0162	0166	0170
104	0170	0175	0179	0183	0187	0191	0195	0199	0204	0208	0212
105	0212	0216	0220	0224	0228	0233	0237	0241	0245	0249	0253
106	0253	0257	0261	0265	0269	0273	0278	0282	0286	0290	0294
107	0294	0298	0302	0306	0310	0314	0318	0322	0326	0330	0334
108	0334	0338	0342	0346	0350	0354	0358	0362	0366	0370	0374
109	0374	0378	0382	0386	0390	0394	0398	0402	0406	0410	0414
110	0414	0418	0422	0426	0430	0434	0438	0441	0445	0449	0453
111	0453	0457	0461	0465	0469	0473	0477	0481	0484	0488	0492
112	0492	0496	0500	0504	0508	0512	0515	0519	0523	0527	0531
113	0531	0535	0538	0542	0546	0550	0554	0558	0561	0565	0569
114	0569	0573	0577	0580	0584	0588	0592	0596	0599	0603	0607
115	0607	0611	0615	0618	0622	0626	0630	0633	0637	0641	0645
116	0645	0648	0652	0656	0660	0663	0667	0671	0674	0678	0682
117	0682	0686	0689	0693	0697	0700	0704	0708	0711	0715	0719
118	0719	0722	0726	0730	0734	0737	0741	0745	0748	0752	0755
119	0755	0759	0763	0766	0770	0774	0777	0781	0785	0788	0792
120	0792	0795	0799	0803	0806	0810	0813	0817	0821	0824	0828
121	0828	0831	0835	0839	0842	0846	0849	0853	0856	0860	0864
122	0864	0867	0871	0874	0878	0881	0885	0888	0892	0896	0899
123	0899	0903	0906	0910	0913	0917	0920	0924	0927	0931	0934
124	0934	0938	0941	0945	0948	0952	0955	0959	0962	0966	0969
125	0969	0973	0976	0980	0983	0986	0990	0993	0997	1000	1004
126	1004	1007	1011	1014	1017	1021	1024	1028	1031	1035	1038
127	1038	1041	1045	1048	1052	1055	1059	1062	1065	1069	1072
128	1072	1075	1079	1082	1086	1089	1092	1096	1099	1103	1106
129	1106	1109	1113	1116	1119	1123	1126	1129	1133	1136	1139
130	1139	1143	1146	1149	1153	1156	1159	1163	1166	1169	1173
131	1173	1176	1179	1183	1186	1189	1193	1196	1199	1202	1206
132	1206	1209	1212	1216	1219	1222	1225	1229	1232	1235	1239
133	1239	1242	1245	1248	1252	1255	1258	1261	1265	1268	1271
134	1271	1274	1278	1281	1284	1287	1290	1294	1297	1300	1303
135	1303	1307	1310	1313	1316	1319	1323	1326	1329	1332	1335
136	1335	1339	1342	1345	1348	1351	1355	1358	1361	1364	1367
137	1367	1370	1374	1377	1380	1383	1386	1389	1392	1396	1399
138	1399	1402	1405	1408	1411	1414	1418	1421	1424	1427	1430
139	1430	1433	1436	1440	1443	1446	1449	1452	1455	1458	1461
140	1461	1464	1467	1471	1474	1477	1480	1483	1486	1489	1492
141	1492	1495	1498	1501	1504	1508	1511	1514	1517	1520	1523
142	1523	1526	1529	1532	1535	1538	1541	1544	1547	1550	1553
143	1553	1556	1559	1562	1565	1569	1572	1575	1578	1581	1584
144	1584	1587	1590	1593	1596	1599	1602	1605	1608	1611	1614
145	1614	1617	1620	1623	1626	1629	1632	1635	1638	1641	1644
146	1644	1647	1649	1652	1655	1658	1661	1664	1667	1670	1673
147	1673	1676	1679	1682	1685	1688	1691	1694	1697	1700	1703
148	1703	1706	1708	1711	1714	1717	1720	1723	1726	1729	1732
149	1732	1735	1738	1741	1744	1746	1749	1752	1755	1758	1761

LOGARITHMS.

N.	0	1	2	3	4	5	6	7	8	9	10
150	1761	1764	1767	1770	1772	1775	1778	1781	1784	1787	1790
151	1790	1793	1796	1798	1801	1804	1807	1810	1813	1816	1818
152	1818	1821	1824	1827	1830	1833	1836	1838	1841	1844	1847
153	1847	1850	1853	1855	1858	1861	1864	1867	1870	1872	1875
154	1875	1878	1881	1884	1886	1889	1892	1895	1898	1901	1903
155	1903	1906	1909	1912	1915	1917	1920	1923	1926	1928	1931
156	1931	1934	1937	1940	1942	1945	1948	1951	1953	1956	1959
157	1959	1962	1965	1967	1970	1973	1976	1978	1981	1984	1987
158	1987	1989	1992	1995	1998	2000	2003	2006	2009	2011	2014
159	2014	2017	2019	2022	2025	2028	2030	2033	2036	2038	2041
160	2041	2044	2047	2049	2052	2055	2057	2060	2063	2066	2068
161	2068	2071	2074	2076	2079	2082	2084	2087	2090	2092	2095
162	2095	2098	2101	2103	2106	2109	2111	2114	2117	2119	2122
163	2122	2125	2127	2130	2133	2135	2138	2140	2143	2146	2148
164	2148	2151	2154	2156	2159	2162	2164	2167	2170	2172	2175
165	2175	2177	2180	2183	2185	2188	2191	2193	2196	2198	2201
166	2201	2204	2206	2209	2212	2214	2217	2219	2222	2225	2227
167	2227	2230	2232	2235	2238	2240	2243	2245	2248	2251	2253
168	2253	2256	2258	2261	2263	2266	2269	2271	2274	2276	2279
169	2279	2281	2284	2287	2289	2292	2294	2297	2299	2302	2304
170	2304	2307	2310	2312	2315	2317	2320	2322	2325	2327	2330
171	2330	2333	2335	2338	2340	2343	2345	2348	2350	2353	2355
172	2355	2358	2360	2363	2365	2368	2370	2373	2375	2378	2380
173	2380	2383	2385	2388	2390	2393	2395	2398	2400	2403	2405
174	2405	2408	2410	2413	2415	2418	2420	2423	2425	2428	2430
175	2430	2433	2435	2438	2440	2443	2445	2448	2450	2453	2455
176	2455	2458	2460	2463	2465	2467	2470	2472	2475	2477	2480
177	2480	2482	2485	2487	2490	2492	2494	2497	2499	2502	2504
178	2504	2507	2509	2512	2514	2516	2519	2521	2524	2526	2529
179	2529	2531	2533	2536	2538	2541	2543	2545	2548	2550	2553
180	2553	2555	2558	2560	2562	2565	2567	2570	2572	2574	2577
181	2577	2579	2582	2584	2586	2589	2591	2594	2596	2598	2601
182	2601	2603	2605	2608	2610	2613	2615	2617	2620	2622	2625
183	2625	2627	2629	2632	2634	2636	2639	2641	2643	2646	2648
184	2648	2651	2653	2655	2658	2660	2662	2665	2667	2669	2672
185	2672	2674	2676	2679	2681	2683	2686	2688	2690	2693	2695
186	2695	2697	2700	2702	2704	2707	2709	2711	2714	2716	2718
187	2718	2721	2723	2725	2728	2730	2732	2735	2737	2739	2742
188	2742	2744	2746	2749	2751	2753	2755	2758	2760	2762	2765
189	2765	2767	2769	2772	2774	2776	2778	2781	2783	2785	2788
190	2788	2790	2792	2794	2797	2799	2801	2804	2806	2808	2810
191	2810	2813	2815	2817	2819	2822	2824	2826	2828	2831	2833
192	2833	2835	2838	2840	2842	2844	2847	2849	2851	2853	2856
193	2856	2858	2860	2862	2865	2867	2869	2871	2874	2876	2878
194	2878	2880	2882	2885	2887	2889	2891	2894	2896	2898	2900
195	2900	2903	2905	2907	2909	2911	2914	2916	2918	2920	2923
196	2923	2925	2927	2929	2931	2934	2936	2938	2940	2942	2945
197	2945	2947	2949	2951	2953	2956	2958	2960	2962	2964	2967
198	2967	2969	2971	2973	2975	2978	2980	2982	2984	2986	2989
199	2989	2991	2993	2995	2997	2999	3002	3004	3006	3008	3010

TABLE 10.

LOGARITHMS.

N	0	1	2	3	4	5	6	7	8	9	P. P. 1	2	3	4	5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	5	7	9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	6
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4

LOGARITHMS.

N.	0	1	2	3	4	5	6	7	8	9	P.P. 1	2	3	4	5
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	3	3
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2

TABLE 11.

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	P. P. 1	2	3	4	5
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4

Table 11 (*continued*).

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	P. P. 1	2	3	4	5
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11

TABLE 12.

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	10
.900	7943	7945	7947	7949	7951	7952	7954	7956	7958	7960	7962
.901	7962	7963	7965	7967	7969	7971	7973	7974	7976	7978	7980
.902	7980	7982	7984	7985	7987	7989	7991	7993	7995	7997	7998
.903	7998	8000	8002	8004	8006	8008	8009	8011	8013	8015	8017
.904	8017	8019	8020	8022	8024	8026	8028	8030	8032	8033	8035
.905	8035	8037	8039	8041	8043	8045	8046	8048	8050	8052	8054
.906	8054	8056	8057	8059	8061	8063	8065	8067	8069	8070	8072
.907	8072	8074	8076	8078	8080	8082	8084	8085	8087	8089	8091
.908	8091	8093	8095	8097	8098	8100	8102	8104	8106	8108	8110
.909	8110	8111	8113	8115	8117	8119	8121	8123	8125	8126	8128
.910	8128	8130	8132	8134	8136	8138	8140	8141	8143	8145	8147
.911	8147	8149	8151	8153	8155	8156	8158	8160	8162	8164	8166
.912	8166	8168	8170	8171	8173	8175	8177	8179	8181	8183	8185
.913	8185	8187	8188	8190	8192	8194	8196	8198	8200	8202	8204
.914	8204	8205	8207	8209	8211	8213	8215	8217	8219	8221	8222
.915	8222	8224	8226	8228	8230	8232	8234	8236	8238	8239	8241
.916	8241	8243	8245	8247	8249	8251	8253	8255	8257	8258	8260
.917	8260	8262	8264	8266	8268	8270	8272	8274	8276	8278	8279
.918	8279	8281	8283	8285	8287	8289	8291	8293	8295	8297	8299
.919	8299	8300	8302	8304	8306	8308	8310	8312	8314	8316	8318
.920	8318	8320	8321	8323	8325	8327	8329	8331	8333	8335	8337
.921	8337	8339	8341	8343	8344	8346	8348	8350	8352	8354	8356
.922	8356	8358	8360	8362	8364	8366	8368	8370	8371	8373	8375
.923	8375	8377	8379	8381	8383	8385	8387	8389	8391	8393	8395
.924	8395	8397	8398	8400	8402	8404	8406	8408	8410	8412	8414
.925	8414	8416	8418	8420	8422	8424	8426	8428	8429	8431	8433
.926	8433	8435	8437	8439	8441	8443	8445	8447	8449	8451	8453
.927	8453	8455	8457	8459	8461	8463	8464	8466	8468	8470	8472
.928	8472	8474	8476	8478	8480	8482	8484	8486	8488	8490	8492
.929	8492	8494	8496	8498	8500	8502	8504	8506	8507	8509	8511
.930	8511	8513	8515	8517	8519	8521	8523	8525	8527	8529	8531
.931	8531	8533	8535	8537	8539	8541	8543	8545	8547	8549	8551
.932	8551	8553	8555	8557	8559	8561	8562	8564	8566	8568	8570
.933	8570	8572	8574	8576	8578	8580	8582	8584	8586	8588	8590
.934	8590	8592	8594	8596	8598	8600	8602	8604	8606	8608	8610
.935	8610	8612	8614	8616	8618	8620	8622	8624	8626	8628	8630
.936	8630	8632	8634	8636	8638	8640	8642	8644	8646	8648	8650
.937	8650	8652	8654	8656	8658	8660	8662	8664	8666	8668	8670
.938	8670	8672	8674	8676	8678	8680	8682	8684	8686	8688	8690
.939	8690	8692	8694	8696	8698	8700	8702	8704	8706	8708	8710
.940	8710	8712	8714	8716	8718	8720	8722	8724	8726	8728	8730
.941	8730	8732	8734	8736	8738	8740	8742	8744	8746	8748	8750
.942	8750	8752	8754	8756	8758	8760	8762	8764	8766	8768	8770
.943	8770	8772	8774	8776	8778	8780	8782	8784	8786	8788	8790
.944	8790	8792	8794	8796	8798	8800	8802	8804	8806	8808	8810
.945	8810	8813	8815	8817	8819	8821	8823	8825	8827	8829	8831
.946	8831	8833	8835	8837	8839	8841	8843	8845	8847	8849	8851
.947	8851	8853	8855	8857	8859	8861	8863	8865	8867	8870	8872
.948	8872	8874	8876	8878	8880	8882	8884	8886	8888	8890	8892
.949	8892	8894	8896	8898	8900	8902	8904	8906	8908	8910	8913

TABLE 12 (*continued*).

ANTILOGARITHMS.

	0	1	2	3	4	5	6	7	8	9	10
.950	8913	8915	8917	8919	8921	8923	8925	8927	8929	8931	8933
.951	8933	8935	8937	8939	8941	8943	8945	8947	8950	8952	8954
.952	8954	8956	8958	8960	8962	8964	8966	8968	8970	8972	8974
.953	8974	8976	8978	8980	8983	8985	8987	8989	8991	8993	8995
.954	8995	8997	8999	9001	9003	9005	9007	9009	9012	9014	9016
.955	9016	9018	9020	9022	9024	9026	9028	9030	9032	9034	9036
.956	9036	9039	9041	9043	9045	9047	9049	9051	9053	9055	9057
.957	9057	9059	9061	9064	9066	9068	9070	9072	9074	9076	9078
.958	9078	9080	9082	9084	9087	9089	9091	9093	9095	9097	9099
.959	9099	9101	9103	9105	9108	9110	9112	9114	9116	9118	9120
.960	9120	9122	9124	9126	9129	9131	9133	9135	9137	9139	9141
.961	9141	9143	9145	9147	9150	9152	9154	9156	9158	9160	9162
.962	9162	9164	9166	9169	9171	9173	9175	9177	9179	9181	9183
.963	9183	9185	9188	9190	9192	9194	9196	9198	9200	9202	9204
.964	9204	9207	9209	9211	9213	9215	9217	9219	9221	9224	9226
.965	9226	9228	9230	9232	9234	9236	9238	9241	9243	9245	9247
.966	9247	9249	9251	9253	9256	9258	9260	9262	9264	9266	9268
.967	9268	9270	9273	9275	9277	9279	9281	9283	9285	9288	9290
.968	9290	9292	9294	9296	9298	9300	9303	9305	9307	9309	9311
.969	9311	9313	9315	9318	9320	9322	9324	9326	9328	9330	9333
.970	9333	9335	9337	9339	9341	9343	9345	9348	9350	9352	9354
.971	9354	9356	9358	9361	9363	9365	9367	9369	9371	9373	9376
.972	9376	9378	9380	9382	9384	9386	9389	9391	9393	9395	9397
.973	9397	9399	9402	9404	9406	9408	9410	9412	9415	9417	9419
.974	9419	9421	9423	9425	9428	9430	9432	9434	9436	9438	9441
.975	9441	9443	9445	9447	9449	9451	9454	9456	9458	9460	9462
.976	9462	9465	9467	9469	9471	9473	9475	9478	9480	9482	9484
.977	9484	9486	9489	9491	9493	9495	9497	9499	9502	9504	9506
.978	9506	9508	9510	9513	9515	9517	9519	9521	9524	9526	9528
.979	9528	9530	9532	9535	9537	9539	9541	9543	9546	9548	9550
.980	9550	9552	9554	9557	9559	9561	9563	9565	9568	9570	9572
.981	9572	9574	9576	9579	9581	9583	9585	9587	9590	9592	9594
.982	9594	9596	9598	9601	9603	9605	9607	9609	9612	9614	9616
.983	9616	9618	9621	9623	9625	9627	9629	9632	9634	9636	9638
.984	9638	9641	9643	9645	9647	9649	9652	9654	9656	9658	9661
.985	9661	9663	9665	9667	9669	9672	9674	9676	9678	9681	9683
.986	9683	9685	9687	9689	9692	9694	9696	9698	9701	9703	9705
.987	9705	9707	9710	9712	9714	9716	9719	9721	9723	9725	9727
.988	9727	9730	9732	9734	9736	9739	9741	9743	9745	9748	9750
.989	9750	9752	9754	9757	9759	9761	9763	9766	9768	9770	9772
.990	9772	9775	9777	9779	9781	9784	9786	9788	9790	9793	9795
.991	9795	9797	9799	9802	9804	9806	9808	9811	9813	9815	9817
.992	9817	9820	9822	9824	9827	9829	9831	9833	9836	9838	9840
.993	9840	9842	9845	9847	9849	9851	9854	9856	9858	9861	9863
.994	9863	9865	9867	9870	9872	9874	9876	9879	9881	9883	9886
.995	9886	9888	9890	9892	9895	9897	9899	9901	9904	9906	9908
.996	9908	9911	9913	9915	9917	9920	9922	9924	9927	9929	9931
.997	9931	9933	9936	9938	9940	9943	9945	9947	9949	9952	9954
.998	9954	9956	9959	9961	9963	9966	9968	9970	9972	9975	9977
.999	9977	9979	9982	9984	9986	9988	9991	9993	9995	9998	0000

TABLE 13.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

(Taken from B. O. Peirce's "Short Table of Integrals," Ginn & Co.)

RADI-ANS.	DE-GREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.0000	0°00′	.0000	∞	1.0000	0.0000	.0000	∞	∞	∞	90°00′	1.5708
0.0029	10	.0029	7.4637	1.0000	.0000	.0029	7.4637	343.77	2.5363	50	1.5679
0.0058	20	.0058	.7648	1.0000	.0000	.0058	.7648	171.89	.2352	40	1.5650
0.0087	30	.0087	.9408	1.0000	.0000	.0087	.9409	114.59	.0591	30	1.5621
0.0116	40	.0116	8.0658	.9999	.0000	.0116	8.0658	85.940	1.9342	20	1.5592
0.0145	50	.0145	.1627	.9999	.0000	.0145	.1627	68.750	.8373	10	1.5563
0.0175	1°00′	.0175	8.2419	.9998	9.9999	.0175	8.2419	57.290	1.7581	89°00′	1.5533
0.0204	10	.0204	.3088	.9998	.9999	.0204	.3089	49.104	.6911	50	1.5504
0.0233	20	.0233	.3668	.9997	.9999	.0233	.3669	42.964	.6331	40	1.5475
0.0262	30	.0262	.4179	.9997	.9999	.0262	.4181	38.188	.5819	30	1.5446
0.0291	40	.0291	.4637	.9996	.9998	.0291	.4638	34.368	.5362	20	1.5417
0.0320	50	.0320	.5050	.9995	.9998	.0320	.5053	31.242	.4947	10	1.5388
0.0349	2°00′	.0349	8.5428	.9994	9.9997	.0349	8.5431	28.636	1.4569	88°00′	1.5359
0.0378	10	.0378	.5776	.9993	.9997	.0378	.5779	26.432	.4221	50	1.5330
0.0407	20	.0407	.6097	.9992	.9996	.0407	.6101	24.542	.3899	40	1.5301
0.0436	30	.0436	.6397	.9990	.9996	.0437	.6401	22.904	.3599	30	1.5272
0.0465	40	.0465	.6677	.9989	.9995	.0466	.6682	21.470	.3318	20	1.5243
0.0495	50	.0494	.6940	.9988	.9995	.0495	.6945	20.206	.3055	10	1.5213
0.0524	3°00′	.0523	8.7188	.9986	9.9994	.0524	8.7194	19.081	1.2806	87°00′	1.5184
0.0553	10	.0552	.7423	.9985	.9993	.0553	.7429	18.075	.2571	50	1.5155
0.0582	20	.0581	.7645	.9983	.9993	.0582	.7652	17.169	.2348	40	1.5126
0.0611	30	.0610	.7857	.9981	.9992	.0612	.7865	16.350	.2135	30	1.5097
0.0640	40	.0640	.8059	.9980	.9991	.0641	.8067	15.605	.1933	20	1.5068
0.0669	50	.0669	.8251	.9978	.9990	.0670	.8261	14.924	.1739	10	1.5039
0.0698	4°00′	.0698	8.8436	.9976	9.9989	.0699	8.8446	14.301	1.1554	86°00′	1.5010
0.0727	10	.0727	.8613	.9974	.9989	.0729	.8624	13.727	.1376	50	1.4981
0.0756	20	.0756	.8783	.9971	.9988	.0758	.8795	13.197	.1205	40	1.4952
0.0785	30	.0785	.8946	.9969	.9987	.0787	.8960	12.706	.1040	30	1.4923
0.0814	40	.0814	.9104	.9967	.9986	.0816	.9118	12.251	.0882	20	1.4893
0.0844	50	.0843	.9256	.9964	.9985	.0846	.9272	11.826	.0728	10	1.4864
0.0873	5°00′	.0872	8.9403	.9962	9.9983	.0875	8.9420	11.430	1.0580	85°00′	1.4835
0.0902	10	.0901	.9545	.9959	.9982	.0904	.9563	11.059	.0437	50	1.4806
0.0931	20	.0929	.9682	.9957	.9981	.0934	.9701	10.712	.0299	40	1.4777
0.0960	30	.0958	.9816	.9954	.9980	.0963	.9836	10.385	.0164	30	1.4748
0.0989	40	.0987	.9945	.9951	.9979	.0992	.9966	10.078	.0034	20	1.4719
0.1018	50	.1016	9.0070	.9948	.9977	.1022	9.0093	9.7882	0.9907	10	1.4690
0.1047	6°00	.1045	9.0192	.9945	9.9976	.1051	9.0216	9.5144	0.9784	84°00′	1.4661
0.1076	10	.1074	.0311	.9942	.9975	.1080	.0336	9.2553	.9664	50	1.4632
0.1105	20	.1103	.0426	.9939	.9973	.1110	.0453	9.0098	.9547	40	1.4603
0.1134	30	.1132	.0539	.9936	.9972	.1139	.0567	8.7769	.9433	30	1.4574
0.1164	40	.1161	.0648	.9932	.9971	.1169	.0678	8.5555	.9322	20	1.4544
0.1193	50	.1190	.0755	.9929	.9969	.1198	.0786	8.3450	.9214	10	1.4515
0.1222	7°00′	.1219	9.0859	.9925	9.9968	.1228	9.0891	8.1443	0.9109	83°00′	1.4486
0.1251	10	.1248	.0961	.9922	.9966	.1257	.0995	7.9530	.9005	50	1.4457
0.1280	20	.1276	.1060	.9918	.9964	.1287	.1096	7.7704	.8904	40	1.4428
0.1309	30	.1305	.1157	.9914	.9963	.1317	.1194	7.5958	.8806	30	1.4399
0.1338	40	.1334	.1252	.9911	.9961	.1346	.1291	7.4287	.8709	20	1.4370
0.1367	50	.1363	.1345	.9907	.9959	.1376	.1385	7.2687	.8615	10	1.4341
0.1396	8°00′	.1392	9.1436	.9903	9.9958	.1405	9.1478	7.1154	0.8522	82°00′	1.4312
0.1425	10	.1421	.1525	.9899	.9956	.1435	.1569	6.9682	.8431	50	1.4283
0.1454	20	.1449	.1612	.9894	.9954	.1465	.1658	6.8269	.8342	40	1.4254
0.1484	30	.1478	.1697	.9890	.9952	.1495	.1745	6.6912	.8255	30	1.4224
0.1513	40	.1507	.1781	.9886	.9950	.1524	.1831	6.5606	.8169	20	1.4195
0.1542	50	.1536	.1863	.9881	.9948	.1554	.1915	6.4348	.8085	10	1.4166
0.1571	9°00′	.1564	9.1943	.9877	9.9946	.1584	9.1997	6.3138	0.8003	81°00′	1.4137
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DE-GREES.	RADI-ANS.
		COSINES.		SINES.		COTAN-GENTS.		TANGENTS.			

TABLE 13 (*continued*).

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.1571	9°00′	.1564	9.1943	.9877	9.9946	.1584	9.1997	6.3138	0.8003	81°00′	1.4137
0.1600	10	.1593	.2022	.9872	.9944	.1614	.2078	6.1970	.7922	50	1.4108
0.1629	20	.1622	.2100	.9868	.9942	.1644	.2158	6.0844	.7842	40	1.4079
0.1658	30	.1650	.2176	.9863	.9940	.1673	.2236	5.9758	.7764	30	1.4050
0.1687	40	.1679	.2251	.9858	.9938	.1703	.2313	5.8708	.7687	20	1.4021
0.1716	50	.1708	.2324	.9853	.9936	.1733	.2389	5.7694	.7611	10	1.3992
0.1745	10°00′	.1736	9.2397	.9848	9.9934	.1763	9.2463	5.6713	0.7537	80°00′	1.3963
0.1774	10	.1765	.2468	.9843	.9931	.1793	.2536	5.5764	.7464	50	1.3934
0.1804	20	.1794	.2538	.9838	.9929	.1823	.2609	5.4845	.7391	40	1.3904
0.1833	30	.1822	.2606	.9833	.9927	.1853	.2680	5.3955	.7320	30	1.3875
0.1862	40	.1851	.2674	.9827	.9924	.1883	.2750	5.3093	.7250	20	1.3846
0.1891	50	.1880	.2740	.9822	.9922	.1914	.2819	5.2257	.7181	10	1.3817
0.1920	11°00′	.1908	9.2806	.9816	9.9919	.1944	9.2887	5.1446	0.7113	79°00′	1.3788
0.1949	10	.1937	.2870	.9811	.9917	.1974	.2953	5.0658	.7047	50	1.3759
0.1978	20	.1965	.2934	.9805	.9914	.2004	.3020	4.9894	.6980	40	1.3730
0.2007	30	.1994	.2997	.9799	.9912	.2035	.3085	4.9152	.6915	30	1.3701
0.2036	40	.2022	.3058	.9793	.9909	.2065	.3149	4.8430	.6851	20	1.3672
0.2065	50	.2051	.3119	.9787	.9907	.2095	.3212	4.7729	.6788	10	1.3643
0.2094	12°00′	.2079	9.3179	.9781	9.9904	.2126	9.3275	4.7046	0.6725	78°00′	1.3614
0.2123	10	.2108	.3238	.9775	.9901	.2156	.3336	4.6382	.6664	50	1.3584
0.2153	20	.2136	.3296	.9769	.9899	.2186	.3397	4.5736	.6603	40	1.3555
0.2182	30	.2164	.3353	.9763	.9896	.2217	.3458	4.5107	.6542	30	1.3526
0.2211	40	.2193	.3410	.9757	.9893	.2247	.3517	4.4494	.6483	20	1.3497
0.2240	50	.2221	.3466	.9750	.9890	.2278	.3576	4.3897	.6424	10	1.3468
0.2269	13°00′	.2250	9.3521	.9744	9.9887	.2309	9.3634	4.3315	0.6366	77°00′	1.3439
0.2298	10	.2278	.3575	.9737	.9884	.2339	.3691	4.2747	.6309	50	1.3410
0.2327	20	.2306	.3629	.9730	.9881	.2370	.3748	4.2193	.6252	40	1.3381
0.2356	30	.2334	.3682	.9724	.9878	.2401	.3804	4.1653	.6196	30	1.3352
0.2385	40	.2363	.3734	.9717	.9875	.2432	.3859	4.1126	.6141	20	1.3323
0.2414	50	.2391	.3786	.9710	.9872	.2462	.3914	4.0611	.6086	10	1.3294
0.2443	14°00′	.2419	9.3837	.9703	9.9869	.2493	9.3968	4.0108	0.6032	76°00′	1.3265
0.2473	10	.2447	.3887	.9696	.9866	.2524	.4021	3.9617	.5979	50	1.3235
0.2502	20	.2476	.3937	.9689	.9863	.2555	.4074	3.9136	.5926	40	1.3206
0.2531	30	.2504	.3986	.9681	.9859	.2586	.4127	3.8667	.5873	30	1.3177
0.2560	40	.2532	.4035	.9674	.9856	.2617	.4178	3.8208	.5822	20	1.3148
0.2589	50	.2560	.4083	.9667	.9853	.2648	.4230	3.7760	.5770	10	1.3119
0.2618	15°00′	.2588	9.4130	.9659	9.9849	.2679	9.4281	3.7321	0.5719	75°00′	1.3090
0.2647	10	.2616	.4177	.9652	.9846	.2711	.4331	3.6891	.5669	50	1.3061
0.2676	20	.2644	.4223	.9644	.9843	.2742	.4381	3.6470	.5619	40	1.3032
0.2705	30	.2672	.4269	.9636	.9839	.2773	.4430	3.6059	.5570	30	1.3003
0.2734	40	.2700	.4314	.9628	.9836	.2805	.4479	3.5656	.5521	20	1.2974
0.2763	50	.2728	.4359	.9621	.9832	.2836	.4527	3.5261	.5473	10	1.2945
0.2793	16°00′	.2756	9.4403	.9613	9.9828	.2867	9.4575	3.4874	0.5425	74°00′	1.2915
0.2822	10	.2784	.4447	.9605	.9825	.2899	.4622	3.4495	.5378	50	1.2886
0.2851	20	.2812	.4491	.9596	.9821	.2931	.4669	3.4124	.5331	40	1.2857
0.2880	30	.2840	.4533	.9588	.9817	.2962	.4716	3.3759	.5284	30	1.2828
0.2909	40	.2868	.4576	.9580	.9814	.2994	.4762	3.3402	.5238	20	1.2799
0.2938	50	.2896	.4618	.9572	.9810	.3026	.4808	3.3052	.5192	10	1.2770
0.2967	17°00′	.2924	9.4659	.9563	9.9806	.3057	9.4853	3.2709	0.5147	73°00′	1.2741
0.2996	10	.2952	.4700	.9555	.9802	.3089	.4898	3.2371	.5102	50	1.2712
0.3025	20	.2979	.4741	.9546	.9798	.3121	.4943	3.2041	.5057	40	1.2683
0.3054	30	.3007	.4781	.9537	.9794	.3153	.4987	3.1716	.5013	30	1.2654
0.3083	40	.3035	.4821	.9528	.9790	.3185	.5031	3.1397	.4969	20	1.2625
0.3113	50	.3062	.4861	.9520	.9786	.3217	.5075	3.1084	.4925	10	1.2595
0.3142	18°00′	.3090	9.4900	.9511	9.9782	.3249	9.5118	3.0777	0.4882	72°00′	1.2566
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	DEGREES.	RADIANS.
		COSINES.		SINES.		COTANGENTS.		TANGENTS.			

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES. Nat.	SINES. Log.	COSINES. Nat.	COSINES. Log.	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.		
0.3142	18°00′	.3090	9.4900	.9511	9.9782	.3249	9.5118	3.0777	0.4882	72°00′	1.2566
0.3171	10	.3118	.4939	.9502	.9778	.3281	.5161	3.0475	.4839	50	1.2537
0.3200	20	.3145	.4977	.9492	.9774	.3314	.5203	3.0178	.4797	40	1.2508
0.3229	30	.3173	.5015	.9483	.9770	.3346	.5245	2.9887	.4755	30	1.2479
0.3258	40	.3201	.5052	.9474	.9765	.3378	.5287	2.9600	.4713	20	1.2450
0.3287	50	.3228	.5090	.9465	.9761	.3411	.5329	2.9319	.4671	10	1.2421
0.3316	19°00′	.3256	9.5126	.9455	9.9757	.3443	9.5370	2.9042	0.4630	71°00′	1.2392
0.3345	10	.3283	.5163	.9446	.9752	.3476	.5411	2.8770	.4589	50	1.2363
0.3374	20	.3311	.5199	.9436	.9748	.3508	.5451	2.8502	.4549	40	1.2334
0.3403	30	.3338	.5235	.9426	.9743	.3541	.5491	2.8239	.4509	30	1.2305
0.3432	40	.3365	.5270	.9417	.9739	.3574	.5531	2.7980	.4469	20	1.2275
0.3462	50	.3393	.5306	.9407	.9734	.3607	.5571	2.7725	.4429	10	1.2246
0.3491	20°00′	.3420	9.5341	.9397	9.9730	.3640	9.5611	2.7475	0.4389	70°00′	1.2217
0.3520	10	.3448	.5375	.9387	.9725	.3673	.5650	2.7228	.4350	50	1.2188
0.3549	20	.3475	.5409	.9377	.9721	.3706	.5689	2.6985	.4311	40	1.2159
0.3578	30	.3502	.5443	.9367	.9716	.3739	.5727	2.6746	.4273	30	1.2130
0.3607	40	.3529	.5477	.9356	.9711	.3772	.5766	2.6511	.4234	20	1.2101
0.3636	50	.3557	.5510	.9346	.9706	.3805	.5804	2.6279	.4196	10	1.2072
0.3665	21°00′	.3584	9.5543	.9336	9.9702	.3839	9.5842	2.6051	0.4158	69°00′	1.2043
0.3694	10	.3611	.5576	.9325	.9697	.3872	.5879	2.5826	.4121	50	1.2014
0.3723	20	.3638	.5609	.9315	.9692	.3906	.5917	2.5605	.4083	40	1.1985
0.3752	30	.3665	.5641	.9304	.9687	.3939	.5954	2.5386	.4046	30	1.1956
0.3782	40	.3692	.5673	.9293	.9682	.3973	.5991	2.5172	.4009	20	1.1926
0.3811	50	.3719	.5704	.9283	.9677	.4006	.6028	2.4960	.3972	10	1.1897
0.3840	22°00′	.3746	9.5736	.9272	9.9672	.4040	9.6064	2.4751	0.3936	68°00′	1.1868
0.3869	10	.3773	.5767	.9261	.9667	.4074	.6100	2.4545	.3900	50	1.1839
0.3898	20	.3800	.5798	.9250	.9661	.4108	.6136	2.4342	.3864	40	1.1810
0.3927	30	.3827	.5828	.9239	.9656	.4142	.6172	2.4142	.3828	30	1.1781
0.3956	40	.3854	.5859	.9228	.9651	.4176	.6208	2.3945	.3792	20	1.1752
0.3985	50	.3881	.5889	.9216	.9646	.4210	.6243	2.3750	.3757	10	1.1723
0.4014	23°00′	.3907	9.5919	.9205	9.9640	.4245	9.6279	2.3559	0.3721	67°00′	1.1694
0.4043	10	.3934	.5948	.9194	.9635	.4279	.6314	2.3369	.3686	50	1.1665
0.4072	20	.3961	.5978	.9182	.9629	.4314	.6348	2.3183	.3652	40	1.1636
0.4102	30	.3987	.6007	.9171	.9624	.4348	.6383	2.2998	.3617	30	1.1606
0.4131	40	.4014	.6036	.9159	.9618	.4383	.6417	2.2817	.3583	20	1.1577
0.4160	50	.4041	.6065	.9147	.9613	.4417	.6452	2.2637	.3548	10	1.1548
0.4189	24°00′	.4067	9.6093	.9135	9.9607	.4452	9.6486	2.2460	0.3514	66°00′	1.1519
0.4218	10	.4094	.6121	.9124	.9602	.4487	.6520	2.2286	.3480	50	1.1490
0.4247	20	.4120	.6149	.9112	.9596	.4522	.6553	2.2113	.3447	40	1.1461
0.4276	30	.4147	.6177	.9100	.9590	.4557	.6587	2.1943	.3413	30	1.1432
0.4305	40	.4173	.6205	.9088	.9584	.4592	.6620	2.1775	.3380	20	1.1403
0.4334	50	.4200	.6232	.9075	.9579	.4628	.6654	2.1609	.3346	10	1.1374
0.4363	25°00′	.4226	9.6259	.9063	9.9573	.4663	9.6687	2.1445	0.3313	65°00′	1.1345
0.4392	10	.4253	.6286	.9051	.9567	.4699	.6720	2.1283	.3280	50	1.1316
0.4422	20	.4279	.6313	.9038	.9561	.4734	.6752	2.1123	.3248	40	1.1286
0.4451	30	.4305	.6340	.9026	.9555	.4770	.6785	2.0965	.3215	30	1.1257
0.4480	40	.4331	.6366	.9013	.9549	.4806	.6817	2.0809	.3183	20	1.1228
0.4509	50	.4358	.6392	.9001	.9543	.4841	.6850	2.0655	.3150	10	1.1199
0.4538	26°00′	.4384	9.6418	.8988	9.9537	.4877	9.6882	2.0503	0.3118	64°00′	1.1170
0.4567	10	.4410	.6444	.8975	.9530	.4913	.6914	2.0353	.3086	50	1.1141
0.4596	20	.4436	.6470	.8962	.9524	.4950	.6946	2.0204	.3054	40	1.1112
0.4625	30	.4462	.6495	.8949	.9518	.4986	.6977	2.0057	.3023	30	1.1083
0.4654	40	.4488	.6521	.8936	.9512	.5022	.7009	1.9912	.2991	20	1.1054
0.4683	50	.4514	.6546	.8923	.9505	.5059	.7040	1.9768	.2960	10	1.1025
0.4712	27°00′	.4540	9.6570	.8910	9.9499	.5095	9.7072	1.9626	0.2928	63°00′	1.0996
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.		
		COSINES.		SINES.		COTANGENTS.		TANGENTS.		DEGREES.	RADIANS.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES.		COSINES.		TANGENTS.		COTANGENTS.			
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.		
0.4712	27°00′	.4540	9.6570	.8910	9.9499	.5095	9.7072	1.9626	0.2928	63°00′	1.0996
0.4741	10	.4566	.6595	.8897	.9492	.5132	.7103	1.9486	.2897	50	1.0966
0.4771	20	.4592	.6620	.8884	.9486	.5169	.7134	1.9347	.2866	40	1.0937
0.4800	30	.4617	.6644	.8870	.9479	.5206	.7165	1.9210	.2835	30	1.0908
0.4829	40	.4643	.6668	.8857	.9473	.5243	.7196	1.9074	.2804	20	1.0879
0.4858	50	.4669	.6692	.8843	.9466	.5280	.7226	1.8940	.2774	10	1.0850
0.4887	28°00′	.4695	9.6716	.8829	9.9459	.5317	9.7257	1.8807	0.2743	62°00′	1.0821
0.4916	10	.4720	.6740	.8816	.9453	.5354	.7287	1.8676	.2713	50	1.0792
0.4945	20	.4746	.6763	.8802	.9446	.5392	.7317	1.8546	.2683	40	1.0763
0.4974	30	.4772	.6787	.8788	.9439	.5430	.7348	1.8418	.2652	30	1.0734
0.5003	40	.4797	.6810	.8774	.9432	.5467	.7378	1.8291	.2622	20	1.0705
0.5032	50	.4823	.6833	.8760	.9425	.5505	.7408	1.8165	.2592	10	1.0676
0.5061	29°00′	.4848	9.6856	.8746	9.9418	.5543	9.7438	1.8040	0.2562	61°00′	1.0647
0.5091	10	.4874	.6878	.8732	.9411	.5581	.7467	1.7917	.2533	50	1.0617
0.5120	20	.4899	.6901	.8718	.9404	.5619	.7497	1.7796	.2503	40	1.0588
0.5149	30	.4924	.6923	.8704	.9397	.5658	.7526	1.7675	.2474	30	1.0559
0.5178	40	.4950	.6946	.8689	.9390	.5696	.7556	1.7556	.2444	20	1.0530
0.5207	50	.4975	.6968	.8675	.9383	.5735	.7585	1.7437	.2415	10	1.0501
0.5236	30°00′	.5000	9.6990	.8660	9.9375	.5774	9.7614	1.7321	0.2386	60°00′	1.0472
0.5265	10	.5025	.7012	.8646	.9368	.5812	.7644	1.7205	.2356	50	1.0443
0.5294	20	.5050	.7033	.8631	.9361	.5851	.7673	1.7090	.2327	40	1.0414
0.5323	30	.5075	.7055	.8616	.9353	.5890	.7701	1.6977	.2299	30	1.0385
0.5352	40	.5100	.7076	.8601	.9346	.5930	.7730	1.6864	.2270	20	1.0356
0.5381	50	.5125	.7097	.8587	.9338	.5969	.7759	1.6753	.2241	10	1.0327
0.5411	31°00′	.5150	9.7118	.8572	9.9331	.6009	9.7788	1.6643	0.2212	59°00′	1.0297
0.5440	10	.5175	.7139	.8557	.9323	.6048	.7816	1.6534	.2184	50	1.0268
0.5469	20	.5200	.7160	.8542	.9315	.6088	.7845	1.6426	.2155	40	1.0239
0.5498	30	.5225	.7181	.8526	.9308	.6128	.7873	1.6319	.2127	30	1.0210
0.5527	40	.5250	.7201	.8511	.9300	.6168	.7902	1.6212	.2098	20	1.0181
0.5556	50	.5275	.7222	.8496	.9292	.6208	.7930	1.6107	.2070	10	1.0152
0.5585	32°00′	.5299	9.7242	.8480	9.9284	.6249	9.7958	1.6003	0.2042	58°00′	1.0123
0.5614	10	.5324	.7262	.8465	.9276	.6289	.7986	1.5900	.2014	50	1.0094
0.5643	20	.5348	.7282	.8450	.9268	.6330	.8014	1.5798	.1986	40	1.0065
0.5672	30	.5373	.7302	.8434	.9260	.6371	.8042	1.5697	.1958	30	1.0036
0.5701	40	.5398	.7322	.8418	.9252	.6412	.8070	1.5597	.1930	20	1.0007
0.5730	50	.5422	.7342	.8403	.9244	.6453	.8097	1.5497	.1903	10	0.9977
0.5760	33°00′	.5446	9.7361	.8387	9.9236	.6494	9.8125	1.5399	0.1875	57°00′	0.9948
0.5789	10	.5471	.7380	.8371	.9228	.6536	.8153	1.5301	.1847	50	0.9919
0.5818	20	.5495	.7400	.8355	.9219	.6577	.8180	1.5204	.1820	40	0.9890
0.5847	30	.5519	.7419	.8339	.9211	.6619	.8208	1.5108	.1792	30	0.9861
0.5876	40	.5544	.7438	.8323	.9203	.6661	.8235	1.5013	.1765	20	0.9832
0.5905	50	.5568	.7457	.8307	.9194	.6703	.8263	1.4919	.1737	10	0.9803
0.5934	34°00′	.5592	9.7476	.8290	9.9186	.6745	9.8290	1.4826	0.1710	56°00′	0.9774
0.5963	10	.5616	.7494	.8274	.9177	.6787	.8317	1.4733	.1683	50	0.9745
0.5992	20	.5640	.7513	.8258	.9169	.6830	.8344	1.4641	.1656	40	0.9716
0.6021	30	.5664	.7531	.8241	.9160	.6873	.8371	1.4550	.1629	30	0.9687
0.6050	40	.5688	.7550	.8225	.9151	.6916	.8398	1.4460	.1602	20	0.9657
0.6080	50	.5712	.7568	.8208	.9142	.6959	.8425	1.4370	.1575	10	0.9628
0.6109	35°00′	.5736	9.7586	.8192	9.9134	.7002	9.8452	1.4281	0.1548	55°00′	0.9599
0.6138	10	.5760	.7604	.8175	.9125	.7046	.8479	1.4193	.1521	50	0.9570
0.6167	20	.5783	.7622	.8158	.9116	.7089	.8506	1.4106	.1494	40	0.9541
0.6196	30	.5807	.7640	.8141	.9107	.7133	.8533	1.4019	.1467	30	0.9512
0.6225	40	.5831	.7657	.8124	.9098	.7177	.8559	1.3934	.1441	20	0.9483
0.6254	50	.5854	.7675	.8107	.9089	.7221	.8586	1.3848	.1414	10	0.9454
0.6283	36°00′	.5878	9.7692	.8090	9.9080	.7265	9.8613	1.3764	0.1387	54°00′	0.9425
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.		
		COSINES.		SINES.		COTANGENTS.		TANGENTS.		DEGREES.	RADIANS.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	DEGREES.	SINES.		COSINES.		TANGENTS.		COTANGENTS.			
		Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.		
0.6283	36°00′	.5878	9.7692	.8090	9.9080	.7265	9.8613	1.3764	0.1387	54°00′	0.9425
0.6312	10	.5901	.7710	.8073	.9070	.7310	.8639	1.3680	.1361	50	0.9396
0.6341	20	.5925	.7727	.8056	.9061	.7355	.8666	1.3597	.1334	40	0.9367
0.6370	30	.5948	.7744	.8039	.9052	.7400	.8692	1.3514	.1308	30	0.9338
0.6400	40	.5972	.7761	.8021	.9042	.7445	.8718	1.3432	.1282	20	0.9308
0.6429	50	.5995	.7778	.8004	.9033	.7490	.8745	1.3351	.1255	10	0.9279
0.6458	37°00′	.6018	9.7795	.7986	9.9023	.7536	9.8771	1.3270	0.1229	53°00′	0.9250
0.6487	10	.6041	.7811	.7969	.9014	.7581	.8797	1.3190	.1203	50	0.9221
0.6516	20	.6065	.7828	.7951	.9004	.7627	.8824	1.3111	.1176	40	0.9192
0.6545	30	.6088	.7844	.7934	.8995	.7673	.8850	1.3032	.1150	30	0.9163
0.6574	40	.6111	.7861	.7916	.8985	.7720	.8876	1.2954	.1124	20	0.9134
0.6603	50	.6134	.7877	.7898	.8975	.7766	.8902	1.2876	.1098	10	0.9105
0.6632	38°00′	.6157	9.7893	.7880	9.8965	.7813	9.8928	1.2799	0.1072	52°00′	0.9076
0.6661	10	.6180	.7910	.7862	.8955	.7860	.8954	1.2723	.1046	50	0.9047
0.6690	20	.6202	.7926	.7844	.8945	.7907	.8980	1.2647	.1020	40	0.9018
0.6720	30	.6225	.7941	.7826	.8935	.7954	.9006	1.2572	.0994	30	0.8988
0.6749	40	.6248	.7957	.7808	.8925	.8002	.9032	1.2497	.0968	20	0.8959
0.6778	50	.6271	.7973	.7790	.8915	.8050	.9058	1.2423	.0942	10	0.8930
0.6807	39°00′	.6293	9.7989	.7771	9.8905	.8098	9.9084	1.2349	0.0916	51°00′	0.8901
0.6836	10	.6316	.8004	.7753	.8895	.8146	.9110	1.2276	.0890	50	0.8872
0.6865	20	.6338	.8020	.7735	.8884	.8195	.9135	1.2203	.0865	40	0.8843
0.6894	30	.6361	.8035	.7716	.8874	.8243	.9161	1.2131	.0839	30	0.8814
0.6923	40	.6383	.8050	.7698	.8864	.8292	.9187	1.2059	.0813	20	0.8785
0.6952	50	.6406	.8066	.7679	.8853	.8342	.9212	1.1988	.0788	10	0.8756
0.6981	40°00′	.6428	9.8081	.7660	9.8843	.8391	9.9238	1.1918	0.0762	50°00′	0.8727
0.7010	10	.6450	.8096	.7642	.8832	.8441	.9264	1.1847	.0736	50	0.8698
0.7039	20	.6472	.8111	.7623	.8821	.8491	.9289	1.1778	.0711	40	0.8668
0.7069	30	.6494	.8125	.7604	.8810	.8541	.9315	1.1708	.0685	30	0.8639
0.7098	40	.6517	.8140	.7585	.8800	.8591	.9341	1.1640	.0659	20	0.8610
0.7127	50	.6539	.8155	.7566	.8789	.8642	.9366	1.1571	.0634	10	0.8581
0.7156	41°00′	.6561	9.8169	.7547	9.8778	.8693	9.9392	1.1504	0.0608	49°00′	0.8552
0.7185	10	.6583	.8184	.7528	.8767	.8744	.9417	1.1436	.0583	50	0.8523
0.7214	20	.6604	.8198	.7509	.8756	.8796	.9443	1.1369	.0557	40	0.8494
0.7243	30	.6626	.8213	.7490	.8745	.8847	.9468	1.1303	.0532	30	0.8465
0.7272	40	.6648	.8227	.7470	.8733	.8899	.9494	1.1237	.0506	20	0.8436
0.7301	50	.6670	.8241	.7451	.8722	.8952	.9519	1.1171	.0481	10	0.8407
0.7330	42°00′	.6691	9.8255	.7431	9.8711	.9004	9.9544	1.1106	0.0456	48°00′	0.8378
0.7359	10	.6713	.8269	.7412	.8699	.9057	.9570	1.1041	.0430	50	0.8348
0.7389	20	.6734	.8283	.7392	.8688	.9110	.9595	1.0977	.0405	40	0.8319
0.7418	30	.6756	.8297	.7373	.8676	.9163	.9621	1.0913	.0379	30	0.8290
0.7447	40	.6777	.8311	.7353	.8665	.9217	.9646	1.0850	.0354	20	0.8261
0.7476	50	.6799	.8324	.7333	.8653	.9271	.9671	1.0786	.0329	10	0.8232
0.7505	43°00′	.6820	9.8338	.7314	9.8641	.9325	9.9697	1.0724	0.0303	47°00′	0.8203
0.7534	10	.6841	.8351	.7294	.8629	.9380	.9722	1.0661	.0278	50	0.8174
0.7563	20	.6862	.8365	.7274	.8618	.9435	.9747	1.0599	.0253	40	0.8145
0.7592	30	.6884	.8378	.7254	.8606	.9490	.9772	1.0538	.0228	30	0.8116
0.7621	40	.6905	.8391	.7234	.8594	.9545	.9798	1.0477	.0202	20	0.8087
0.7650	50	.6926	.8405	.7214	.8582	.9601	.9823	1.0416	.0177	10	0.8058
0.7679	44°00′	.6947	9.8418	.7193	9.8569	.9657	9.9848	1.0355	0.0152	46°00′	0.8029
0.7709	10	.6967	.8431	.7173	.8557	.9713	.9874	1.0295	.0126	50	0.7999
0.7738	20	.6988	.8444	.7153	.8545	.9770	.9899	1.0235	.0101	40	0.7970
0.7767	30	.7009	.8457	.7133	.8532	.9827	.9924	1.0176	.0076	30	0.7941
0.7796	40	.7030	.8469	.7112	.8520	.9884	.9949	1.0117	.0051	20	0.7912
0.7825	50	.7050	.8482	.7092	.8507	.9942	.9975	1.0058	.0025	10	0.7883
0.7854	45°00′	.7071	9.8495	.7071	9.8495	1.0000	0.0000	1.0000	0.0000	45°00′	0.7854
		Nat.	Log.	Nat	Log.	Nat.	Log.	Nat.	Log.		
		COSINES.		SINES.		COTANGENTS.		TANGENTS.		DEGREES.	RADIANS.

Table 14.

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
0.00	0.00000	— ∞	1.00000	0.00000	— ∞	— ∞	∞	∞	00°00′
.01	.01000	7.99999	0.99995	9.99998	0.01000	8.00001	99.997	1.99999	00 34
.02	.02000	8.30100	.99980	.99991	.02000	.30109	49.993	.69891	01 09
.03	.03000	.47706	.99955	.99980	.03001	.47725	33.323	.52275	01 43
.04	.03999	.60194	.99920	.99965	.04002	.60229	24.987	.39771	02 18
0.05	0.04998	8.69879	0.99875	9.99946	0.05004	8.69933	19.983	1.30067	02°52′
.06	.05996	.77789	.99820	.99922	.06007	.77867	16.647	.22133	03 26
.07	.06994	.84474	.99755	.99894	.07011	.84581	14.262	.15419	04 01
.08	.07991	.90263	.99680	.99861	.08017	.90402	12.473	.09598	04 35
.09	.08988	.95366	.99595	.99824	.09024	.95542	11.081	.04458	05 09
0.10	0.09983	8.99928	0.99500	9.99782	0.10033	9.00145	9.9666	0.99855	05°44′
.11	.10978	9.04052	.99396	.99737	.11045	.04315	9.0542	.95685	06 18
.12	.11971	.07814	.99281	.99687	.12058	.08127	8.2933	.91873	06 53
.13	.12963	.11272	.99156	.99632	.13074	.11640	7.6489	.88360	07 27
.14	.13954	.14471	.99022	.99573	.14092	.14898	7.0961	.85102	08 01
0.15	0.14944	9.17446	0.98877	9.99510	0.15114	9.17937	6.6166	0.82063	08°36′
.16	.15932	.20227	.98723	.99442	.16138	.20785	6.1966	.79215	09 10
.17	.16918	.22836	.98558	.99369	.17166	.23466	5.8256	.76534	09 44
.18	.17903	.25292	.98384	.99293	.18197	.26000	5.4954	.74000	10 19
.19	.18886	.27614	.98200	.99211	.19232	.28402	5.1997	.71598	10 53
0.20	0.19867	9.29813	0.98007	9.99126	0.20271	9.30688	4.9332	0.69312	11°28′
.21	.20846	.31902	.97803	.99035	.21314	.32867	4.6917	.67133	12 02
.22	.21823	.33891	.97590	.98940	.22362	.34951	4.4719	.65049	12 36
.23	.22798	.35789	.97367	.98841	.23414	.36948	4.2709	.63052	13 11
.24	.23770	.37603	.97134	.98737	.24472	.38866	4.0864	.61134	13 45
0.25	0.24740	9.39341	0.96891	9.98628	0.25534	9.40712	3.9163	0.59288	14°19′
.26	.25708	.41007	.96639	.98515	.26602	.42491	3.7592	.57509	14 54
.27	.26673	.42607	.96377	.98397	.27676	.44210	3.6133	.55790	15 28
.28	.27636	.44147	.96106	.98275	.28755	.45872	3.4776	.54128	16 03
.29	.28595	.45629	.95824	.98148	.29841	.47482	3.3511	.52518	16 37
0.30	0.29552	9.47059	0.95534	9.98016	0.30934	9.49043	3.2327	0.50957	17°11′
.31	.30506	.48438	.95233	.97879	.32033	.50559	3.1218	.49441	17 46
.32	.31457	.49771	.94924	.97737	.33139	.52034	3.0176	.47966	18 20
.33	.32404	.51060	.94604	.97591	.34252	.53469	2.9195	.46531	18 54
.34	.33349	.52308	.94275	.97440	.35374	.54868	2.8270	.45132	19 29
0.35	0.34290	9.53516	0.93937	9.97284	0.36503	9.56233	2.7395	0.43767	20°03′
.36	.35227	.54688	.93590	.97123	.37640	.57565	2.6567	.42435	20 38
.37	.36162	.55825	.93233	.96957	.38786	.58868	2.5782	.41132	21 12
.38	.37092	.56928	.92866	.96786	.39941	.60142	2.5037	.39858	21 46
.39	.38019	.58000	.92491	.96610	.41105	.61390	2.4328	.38610	22 21
0.40	0.38942	9.59042	0.92106	9.96429	0.42279	9.62613	2.3652	0.37387	22°55′
.41	.39861	.60055	.91712	.96243	.43463	.63812	2.3008	.36188	23 29
.42	.40776	.61041	.91309	.96051	.44657	.64989	2.2393	.35011	24 04
.43	.41687	.62000	.90897	.95855	.45862	.66145	2.1804	.33855	24 38
.44	.42594	.62935	.90475	.95653	.47078	.67282	2.1241	.32718	25 13
0.45	0.43497	9.63845	0.90045	9.95446	0.48306	9.68400	2.0702	0.31600	25°47′
.46	.44395	.64733	.89605	.95233	.49545	.69500	2.0184	.30500	26 21
.47	.45289	.65599	.89157	.95015	.50797	.70583	1.9686	.29417	26 56
.48	.46178	.66443	.88699	.94792	.52061	.71651	1.9208	.28349	27 30
.49	.47063	.67268	.88233	.94563	.53339	.72704	1.8748	.27296	28 04
0.50	0.47943	9.68072	0.87758	9.94329	0.54630	9.73743	1.8305	0.26257	28°39′

TABLE 14 (*continued*).

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
0.50	0.47943	9.68072	0.87758	9.94329	0.54630	9.73743	1.8305	0.26257	28°39′
.51	.48818	.68858	.87274	.94089	.55936	.74769	.7878	.25231	29 13
.52	.49688	.69625	.86782	.93843	.57256	.75782	.7465	.24218	29 48
.53	.50553	.70375	.86281	.93591	.58592	.76784	.7067	.23216	30 22
.54	.51414	.71108	.85771	.93334	.59943	.77774	.6683	.22226	30 56
0.55	0.52269	9.71824	0.85252	9.93071	0.61311	9.78754	1.6310	0.21246	31°31′
.56	.53119	.72525	.84726	.92801	.62695	.79723	.5950	.20277	32 05
.57	.53963	.73210	.84190	.92526	.64097	.80684	.5601	.19316	32 40
.58	.54802	.73880	.83646	.92245	.65517	.81635	.5263	.18365	33 14
.59	.55636	.74536	.83094	.91957	.66956	.82579	.4935	.17421	33 48
0.60	0.56464	9.75177	0.82534	9.91663	0.68414	9.83514	1.4617	0.16486	34°23′
.61	.57287	.75805	.81965	.91363	.69892	.84443	.4308	.15557	34 57
.62	.58104	.76420	.81388	.91056	.71391	.85364	.4007	.14636	35 31
.63	.58914	.77022	.80803	.90743	.72911	.86280	.3715	.13720	36 06
.64	.59720	.77612	.80210	.90423	.74454	.87189	.3431	.12811	36 40
0.65	0.60519	9.78189	0.79608	9.90096	0.76020	9.88093	1.3154	0.11907	37°15′
.66	.61312	.78754	.78999	.89762	.77610	.88992	.2885	.11008	37 49
.67	.62099	.79308	.78382	.89422	.79225	.89886	.2622	.10114	38 23
.68	.62879	.79851	.77757	.89074	.80866	.90777	.2366	.09223	38 58
.69	.63654	.80382	.77125	.88719	.82534	.91663	.2116	.08337	39 32
0.70	0.64422	9.80903	0.76484	9.88357	0.84229	9.92546	1.1872	0.07454	40°06′
.71	.65183	.81414	.75836	.87988	.85953	.93426	.1634	.06574	40 41
.72	.65938	.81914	.75181	.87611	.87707	.94303	.1402	.05697	41 15
.73	.66687	.82404	.74517	.87226	.89492	.95178	.1174	.04822	41 50
.74	.67429	.82885	.73847	.86833	.91309	.96051	.0952	.03949	42 24
0.75	0.68164	9.83355	0.73169	9.86433	0.93160	9.96923	1.0734	0.03077	42°58′
.76	.68892	.83817	.72484	.86024	.95045	.97793	.0521	.02207	43 33
.77	.69614	.84269	.71791	.85607	.96967	.98662	.0313	.01338	44 07
.78	.70328	.84713	.71091	.85182	.98926	9.99531	1.0109	.00469	44 41
.79	.71035	.85147	.70385	.84748	1.0092	0.00400	0.99084	9.99600	45 16
0.80	0.71736	9.85573	0.69671	9.84305	1.0296	0.01268	0.97121	9.98732	45°50′
.81	.72429	.85991	.68950	.83853	.0505	.02138	.95197	.97862	46 25
.82	.73115	.86400	.68222	.83393	.0717	.03008	.93309	.96992	46 59
.83	.73793	.86802	.67488	.82922	.0934	.03879	.91455	.96121	47 33
.84	.74464	.87195	.66746	.82443	.1156	.04752	.89635	.95248	48 08
0.85	0.75128	9.87580	0.65998	9.81953	1.1383	0.05627	0.87848	9.94373	48°42′
.86	.75784	.87958	.65244	.81454	.1616	.06504	.86091	.93496	49 16
.87	.76433	.88328	.64483	.80944	.1853	.07384	.84365	.92616	49 51
.88	.77074	.88691	.63715	.80424	.2097	.08266	.82668	.91734	50 25
.89	.77707	.89046	.62941	.79894	.2346	.09153	.80998	.90847	51 00
0.90	0.78333	9.89394	0.62161	9.79352	1.2602	0.10043	0.79355	9.89957	51°34′
.91	.78950	.89735	.61375	.78799	.2864	.10937	.77738	.89063	52 08
.92	.79560	.90070	.60582	.78234	.3133	.11835	.76146	.88165	52 43
.93	.80162	.90397	.59783	.77658	.3409	.12739	.74578	.87261	53 17
.94	.80756	.90717	.58979	.77070	.3692	.13648	.73034	.86352	53 51
0.95	0.81342	9.91031	0.58168	9.76469	1.3984	0.14563	0.71511	9.85437	54°26′
.96	.81919	.91339	.57352	.75855	.4284	.15484	.70010	.84516	55 00
.97	.82489	.91639	.56530	.75228	.4592	.16412	.68531	.83588	55 35
.98	.83050	.91934	.55702	.74587	.4910	.17347	.67071	.82653	56 09
.99	.83603	.92222	.54869	.73933	.5237	.18289	.65631	.81711	56 43
1.00	0.84147	9.92504	0.54030	9.73264	1.5574	0.19240	0.64209	9.80760	57°18′

CIRCULAR (TRIGONOMETRIC) FUNCTIONS.

RADIANS.	SINES.		COSINES.		TANGENTS.		COTANGENTS.		DEGREES.
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
1.00	0.84147	9.92504	0.54030	9.73264	1.5574	0.19240	0.64209	9.80760	57°18′
.01	.84683	.92780	.53186	.72580	.5922	.20200	.62806	.79800	57 52
.02	.85211	.93049	.52337	.71881	.6281	.21169	.61420	.78831	58 27
.03	.85730	.93313	.51482	.71165	.6652	.22148	.60051	.77852	59 01
.04	.86240	.93571	.50622	.70434	.7036	.23137	.58699	.76863	59 35
1.05	0.86742	9.93823	0.49757	9.69686	1.7433	0.24138	0.57362	9.75862	60°10′
.06	.87236	.94069	.48887	.68920	.7844	.25150	.56040	.74850	60 44
.07	.87720	.94310	.48012	.68135	.8270	.26175	.54734	.73825	61 18
.08	.88196	.94545	.47133	.67332	.8712	.27212	.53441	.72788	61 53
.09	.88663	.94774	.46249	.66510	.9171	.28264	.52162	.71736	62 27
1.10	0.89121	9.94998	0.45360	9.65667	1.9648	0.29331	0.50897	9.70669	63°02′
.11	.89570	.95216	.44466	.64803	2.0143	.30413	.49644	.69587	63 36
.12	.90010	.95429	.43568	.63917	.0660	.31512	.48404	.68488	64 10
.13	.90441	.95637	.42666	.63008	.1198	.32628	.47175	.67372	64 45
.14	.90863	.95839	.41759	.62075	.1759	.33763	.45959	.66237	65 19
1.15	0.91276	9.96036	0.40849	9.61118	2.2345	0.34918	0.44753	9.65082	65°53′
.16	.91680	.96228	.39934	.60134	.2958	.36093	.43558	.63907	66 28
.17	.92075	.96414	.39015	.59123	.3600	.37291	.42373	.62709	67 02
.18	.92461	.96596	.38092	.58084	.4273	.38512	.41199	.61488	67 37
.19	.92837	.96772	.37166	.57015	.4979	.39757	.40034	.60243	68 11
1.20	0.93204	9.96943	0.36236	9.55914	2.5722	0.41030	0.38878	9.58970	68°45′
.21	.93562	.97110	.35302	.54780	.6503	.42330	.37731	.57670	69 20
.22	.93910	.97271	.34365	.53611	.7328	.43660	.36593	.56340	69 54
.23	.94249	.97428	.33424	.52406	.8198	.45022	.35463	.54978	70 28
.24	.94578	.97579	.32480	.51161	.9119	.46418	.34341	.53582	71 03
1.25	0.94898	9.97726	0.31532	9.49875	3.0096	0.47850	0.33227	9.52150	71°37′
.26	.95209	.97868	.30582	.48546	.1133	.49322	.32121	.50678	72 12
.27	.95510	.98005	.29628	.47170	.2236	.50835	.31021	.49165	72 46
.28	.95802	.98137	.28672	.45745	.3413	.52392	.29928	.47608	73 20
.29	.96084	.98265	.27712	.44267	.4672	.53998	.28842	.46002	73 55
1.30	0.96356	9.98388	0.26750	9.42732	3.6021	0.55656	0.27762	9.44344	74°29′
.31	.96618	.98506	.25785	.41137	.7471	.57369	.26687	.42631	75 03
.32	.96872	.98620	.24818	.39476	.9033	.59144	.25619	.40856	75 38
.33	.97115	.98729	.23848	.37744	4.0723	.60984	.24556	.39016	76 12
.34	.97348	.98833	.22875	.35937	.2556	.62896	.23498	.37104	76 47
1.35	0.97572	9.98933	0.21901	9.34046	4.4552	0.64887	0.22446	9.35113	77°21′
.36	.97786	.99028	.20924	.32064	.6734	.66964	.21398	.33036	77 55
.37	.97991	.99119	.19945	.29983	.9131	.69135	.20354	.30865	78 30
.38	.98185	.99205	.18964	.27793	5.1774	.71411	.19315	.28589	79 04
.39	.98370	.99286	.17981	.25482	.4707	.73804	.18279	.26196	79 38
1.40	0.98545	9.99363	0.16997	9.23036	5.7979	0.76327	0.17248	9.23673	80°13′
.41	.98710	.99436	.16010	.20440	6.1654	.78996	.16220	.21004	80 47
.42	.98865	.99504	.15023	.17674	6.5811	.81830	.15195	.18170	81 22
.43	.99010	.99568	.14033	.14716	7.0555	.84853	.14173	.15147	81 56
.44	.99146	.99627	.13042	.11536	7.6018	.88092	.13155	.11908	82 30
1.45	0.99271	9.99682	0.12050	9.08100	8.2381	0.91583	0.12139	9.08417	83°05′
.46	.99387	.99733	.11057	.04364	8.9886	.95369	.11125	.04631	83 39
.47	.99492	.99779	.10063	.00271	9.8874	.99508	.10114	.00492	84 13
.48	.99588	.99821	.09067	8.95747	10.983	1.04074	.09105	8.95926	84 48
.49	.99674	.99858	.08071	.90692	12.350	.09166	.08097	.90834	85 22
1.50	0.99749	9.99891	0.07074	8.84965	14.101	1.14926	0.07091	8.85074	85°57′

CIRCULAR FUNCTIONS AND FACTORIALS.

TABLE 14 (*continued*). — Circular (Trigonometric) Functions.

RADIANS.	SINES. Nat.	SINES. Log	COSINES. Nat.	COSINES. Log	TANGENTS. Nat.	TANGENTS. Log.	COTANGENTS. Nat.	COTANGENTS. Log.	DEGREES.
1.50	0.99749	9.99891	0.07074	8.84965	14.101	1.14926	0.07091	8.85074	85°57′
.51	.99815	.99920	.06076	.78361	16.428	.21559	.06087	.78441	86 31
.52	.99871	.99944	.05077	.70565	19.670	.29379	.05084	.70621	87 05
.53	.99917	.99964	.04079	.61050	24.498	.38914	.04082	.61086	87 40
.54	.99953	.99979	.03079	.48843	32.461	.51136	.03081	.48864	88 14
1.55	0.99978	9.99991	0.02079	8.31796	48.078	1.68195	0.02080	8.31805	88°49′
.56	0.99994	9.99997	.01080	8.03327	92.621	1.96671	.01080	8.03329	89 23
.57	1.00000	0.00000	.00080	6.90109	1255.8	3.09891	.00080	6.90109	89 57
.58	0.99996	9.99998	−.00920	7.96396n	108.65	2.03603	−.00920	7.96397n	90 32
.59	0.99982	9.99992	−.01920	8.28336n	52.067	1.71656	−.01921	8.28344n	91 06
1.60	0.99957	9.99981	−0.02920	8.46538n	34.233	1.53444	−0.02921	8.46556n	91°40′

90° = 1.570 7963 radians.

TABLE 15. — Logarithmic Factorials.

Logarithms of the products 1.2.3. . . . . . *n*, *n* from 1 to 100.

See Table 17 for Factorials 1 to 20.

See Table 31 for log. Γ (*n* + 1), values of *n* between 1 and 2.

n.	log (*n!*)	*n*.	log (*n!*)	*n*.	log (*n!*)	*n*.	log (*n!*)
1	0.000000	**26**	26.605619	**51**	66.190645	**76**	111.275425
2	0.301030	27	28.036983	52	67.906648	77	113.161916
3	0.778151	28	29.484141	53	69.630924	78	115.054011
4	1.380211	29	30.946539	54	71.363318	79	116.951638
5	2.079181	30	32.423660	55	73.103681	80	118.854728
6	2.857332	**31**	33.915022	**56**	74.851869	**81**	120.763213
7	3.702431	32	35.420172	57	76.607744	82	122.677027
8	4.605521	33	36.938686	58	78.371172	83	124.596105
9	5.559763	34	38.470165	59	80.142024	84	126.520384
10	6.559763	35	40.014233	60	81.920175	85	128.449803
11	7.601156	**36**	41.570535	**61**	83.705505	**86**	130.384301
12	8.680337	37	43.138737	62	85.497896	87	132.323821
13	9.794280	38	44.718520	63	87.297237	88	134.268303
14	10.940408	39	46.309585	64	89.103417	89	136.217693
15	12.116500	40	47.911645	65	90.916330	90	138.171936
16	13.320620	**41**	49.524429	**66**	92.735874	**91**	140.130977
17	14.551069	42	51.147678	67	94.561949	92	142.094765
18	15.806341	43	52.781147	68	96.394458	93	144.063248
19	17.085095	44	54.424599	69	98.233307	94	146.036376
20	18.386125	45	56.077812	70	100.078405	95	148.014099
21	19.708344	**46**	57.740570	**71**	101.929663	**96**	149.996371
22	21.050767	47	59.412668	72	103.786996	97	151.983142
23	22.412494	48	61.093909	73	105.650319	98	153.974368
24	23.792706	49	62.784105	74	107.519550	99	155.970004
25	25.190646	50	64.483075	75	109.394612	100	157.970004

Table 16.
HYPERBOLIC FUNCTIONS.

u	sinh. u		cosh. u		tanh. u		coth. u		gd u
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
0.00	0.00000	—∞	1.00000	0.00000	0.00000	—∞	∞	∞	00°00′
.01	.01000	8.00001	.00005	.00002	.01000	7.99999	100.003	2.00001	0 34
.02	.02000	.30106	.00020	.00009	.02000	8.30097	50.007	1.69903	1 09
.03	.03000	.47719	.00045	.00020	.02999	.47699	33.343	1.52301	1 43
.04	.04001	.60218	.00080	.00035	.03998	.60183	25.013	1.39817	2 17
0.05	0.05002	8.69915	1.00125	0.00054	0.04996	8.69861	20.017	1.30139	2 52
.06	.06004	.77841	.00180	.00078	.05993	.77763	16.687	.22237	3 26
.07	.07006	.84545	.00245	.00106	.06989	.84439	14.309	.15561	4 00
.08	.08009	.90355	.00320	.00139	.07983	.90216	12.527	.09784	4 35
.09	.09012	.95483	.00405	.00176	.08976	.95307	11.141	.04693	5 09
0.10	0.10017	9.00072	1.00500	0.00217	0.09967	8.99856	10.0333	1.00144	5 43
.11	.11022	.04227	.00606	.00262	.10956	9.03965	9.1275	0.96035	6 17
.12	.12029	.08022	.00721	.00312	.11943	.07710	8.3733	.92290	6 52
.13	.13037	.11517	.00846	.00366	.12927	.11151	7.7356	.88849	7 26
.14	.14046	.14755	.00982	.00424	.13909	.14330	7.1895	.85670	8 00
0.15	0.15056	9.17772	1.01127	0.00487	0.14889	9.17285	6.7166	0.82715	8 34
.16	.16068	.20597	.01283	.00554	.15865	.20044	6.3032	.79956	9 08
.17	.17082	.23254	.01448	.00625	.16838	.22629	5.9389	.77371	9 42
.18	.18097	.25762	.01624	.00700	.17808	.25062	5.6154	.74938	10 15
.19	.19115	.28136	.01810	.00779	.18775	.27357	5.3263	.72643	10 49
0.20	0.20134	9.30392	1.02007	0.00863	0.19738	9.29529	5.0665	0.70471	11 23
.21	.21155	.32541	.02213	.00951	.20697	.31590	4.8317	.68410	11 57
.22	.22178	.34592	.02430	.01043	.21652	.33549	4.6186	.66451	12 30
.23	.23203	.36555	.02657	.01139	.22603	.35416	4.4242	.64584	13 04
.24	.24231	.38437	.02894	.01239	.23550	.37198	4.2464	.62802	13 37
0.25	0.25261	9.40245	1.03141	0.01343	0.24492	9.38902	4.0830	0.61098	14 11
.26	.26294	.41986	.03399	.01452	.25430	.40534	3.9324	.59466	14 44
.27	.27329	.43663	.03667	.01564	.26362	.42099	3.7933	.57901	15 17
.28	.28367	.45282	.03946	.01681	.27291	.43601	3.6643	.56399	15 50
.29	.29408	.46847	.04235	.01801	.28213	.45046	3.5444	.54954	16 23
0.30	0.30452	9.48362	1.04534	0.01926	0.29131	9.46436	3.4327	0.53564	16 56
.31	.31499	.49830	.04844	.02054	.30044	.47775	.3285	.52225	17 29
.32	.32549	.51254	.05164	.02187	.30951	.49067	.2309	.50933	18 02
.33	.33602	.52637	.05495	.02323	.31852	.50314	.1395	.49686	18 34
.34	.34659	.53981	.05836	.02463	.32748	.51518	.0536	.48482	19 07
0.35	0.35719	9.55290	1.06188	0.02607	0.33638	9.52682	2.9729	0.47318	19 39
.36	.36783	.56564	.06550	.02755	.34521	.53809	.8968	.46191	20 12
.37	.37850	.57807	.06923	.02907	.35399	.54899	.8249	.45101	20 44
.38	.38921	.59019	.07307	.03063	.36271	.55956	.7570	.44044	21 16
.39	.39996	.60202	.07702	.03222	.37136	.56980	.6928	.43020	21 48
0.40	0.41075	9.61358	1.08107	0.03385	0.37995	9.57973	2.6319	0.42027	22 20
.41	.42158	.62488	.08523	.03552	.38847	.58936	.5742	.41064	22 52
.42	.43246	.63594	.08950	.03723	.39693	.59871	.5193	.40129	23 23
.43	.44337	.64677	.09388	.03897	.40532	.60780	.4672	.39220	23 55
.44	.45434	.65738	.09837	.04075	.41364	.61663	.4175	.38337	24 26
0.45	0.46534	9.66777	1.102970	.04256	0.42190	9.62521	2.3702	0.37479	24 57
.46	.47640	.67797	.10768	.04441	.43008	.63355	.3251	.36645	25 28
.47	.48750	.68797	.11250	.04630	.43820	.64167	.2821	.35833	25 59
.48	.49865	.69779	.11743	.04822	.44624	.64957	.2409	.35043	26 30
.49	.50984	.70744	.12247	.05018	.45422	.65726	.2016	.34274	27 01
0.50	0.52110	9.71692	1.12763	0.05217	0.46212	9.66475	2.1640	0.33525	27 31

Table 16 (*continued*).

HYBERBOLIC FUNCTIONS.

u	sinh. u Nat.	sinh. u Log.	cosh. u Nat.	cosh. u Log.	tanh. u Nat.	tanh. u Log.	coth. u Nat.	coth. u Log.	gd u
0.50	0.52110	9.71692	1.12763	0.05217	0.46212	9.66475	2.1640	0.33525	27°31′
.51	.53240	.72624	.13289	.05419	.46995	.67205	.1279	.32795	28 02
.52	.54375	.73540	.13827	.05625	.47770	.67916	.0934	.32084	28 32
.53	.55516	.74442	.14377	.05834	.48538	.68608	.0602	.31392	29 02
.54	.56663	.75330	.14938	.06046	.49299	.69284	.0284	.30716	29 32
0.55	0.57815	9.76204	1.15510	0.06262	0.50052	9.69942	1.9979	0.30058	30 02
.56	.58973	.77065	.16094	.06481	.50798	.70584	.9686	.29416	30 32
.57	.60137	.77914	.16690	.06703	.51536	.71211	.9404	.28789	31 01
.58	.61307	.78751	.17297	.06929	.52267	.71822	.9133	.28178	31 31
.59	.62483	.79576	.17916	.07157	.52990	.72419	.8872	.27581	32 00
0.60	0.63665	9.80390	1.18547	0.07389	0.53705	9.73001	1.8620	0.26999	32 29
.61	.64854	.81194	.19189	.07624	.54413	.73570	.8378	.26430	32 58
.62	.66049	.81987	.19844	.07861	.55113	.74125	.8145	.25875	33 27
.63	.67251	.82770	.20510	.08102	.55805	.74667	.7919	.25333	33 55
.64	.68459	.83543	.21189	.08346	.56490	.75197	.7702	.24803	34 24
0.65	0.69675	9.84308	1.21879	0.08593	0.57167	9.75715	1.7493	0.24285	34 52
.66	.70897	.85063	.22582	.08843	.57836	.76220	.7290	.23780	35 20
.67	.72126	.85809	.23297	.09095	.58498	.76714	.7095	.23286	35 48
.68	.73363	.86548	.24025	.09351	.59152	.77197	.6906	.22803	36 16
.69	.74607	.87278	.24765	.09609	.59798	.77669	.6723	.22331	36 44
0.70	0.75858	9.88000	1.25517	0.09870	0.60437	9.78130	1.6546	0.21870	37 11
.71	.77117	.88715	.26282	.10134	.61068	.78581	.6375	.21419	37 38
.72	.78384	.89423	.27059	.10401	.61691	.79022	.6210	.20978	38 05
.73	.79659	.90123	.27849	.10670	.62307	.79453	.6050	.20547	38 32
.74	.80941	.90817	.28652	.10942	.62915	.79875	.5895	.20125	38 59
0.75	0.82232	9.91504	1.29468	0.11216	0.63515	9.80288	1.5744	0.19712	39 26
.76	.83530	.92185	.30297	.11493	.64108	.80691	.5599	.19309	39 52
.77	.84838	.92859	.31139	.11773	.64693	.81086	.5458	.18914	40 19
.78	.86153	.93527	.31994	.12055	.65271	.81472	.5321	.18528	40 45
.79	.87478	.94190	.32862	.12340	.65841	.81850	.5188	.18150	41 11
0.80	0.88811	9.94846	1.33743	0.12627	0.66404	9.82219	1.5059	0.17781	41 37
.81	.90152	.95498	.34638	.12917	.66959	.82581	.4935	.17419	42 02
.82	.91503	.96144	.35547	.13209	.67507	.82935	.4813	.17065	42 28
.83	.92863	.96784	.36468	.13503	.68048	.83281	.4696	.16719	42 53
.84	.94233	.97420	.37404	.13800	.68581	.83620	.4581	.16380	43 18
0.85	0.95612	9.98051	1.38353	0.14099	0.69107	9.83952	1.4470	0.16048	43 43
.86	.97000	.98677	.39316	.14400	.69626	.84277	.4362	.15723	44 08
.87	.98398	.99299	.40293	.14704	.70137	.84595	.4258	.15405	44 32
.88	.99806	.99916	.41284	.15009	.70642	.84906	.4156	.15094	44 57
.89	1.01224	0.00528	.42289	.15317	.71139	.85211	.4057	.14789	45 21
0.90	1.02652	0.01137	1.43309	0.15627	0.71630	9.85509	1.3961	0.14491	45 45
.91	.04090	.01741	.44342	.15939	.72113	.85801	.3867	.14199	46 09
.92	.05539	.02341	.45390	.16254	.72590	.86088	.3776	.13912	46 33
.93	.06998	.02937	.46453	.16570	.73059	.86368	.3687	.13632	46 56
.94	.08468	.03530	.47530	.16888	.73522	.86642	.3601	.13358	47 20
0.95	1.09948	0.04119	1.48623	0.17208	0.73978	9.86910	1.3517	0.13090	47 43
.96	.11440	.04704	.49729	.17531	.74428	.87173	.3436	.12827	48 06
.97	.12943	.05286	.50851	.17855	.74870	.87431	.3356	.12569	48 29
.98	.14457	.05864	.51988	.18181	.75307	.87683	.3279	.12317	48 51
.99	.15983	.06439	.53141	.18509	.75736	.87930	.3204	.12070	49 14
1.00	1.17520	0.07011	1.54308	0.18839	0.76159	9.88172	1.3130	0.11828	49 36

u	sinh. u Nat.	sinh. u Log.	cosh. u Nat.	cosh. u Log.	tanh. u Nat.	tanh. u Log.	coth u Nat.	coth u Log.	gd u
1.00	1.17520	0.07011	1.54308	0.18839	0.76159	9.88172	1.3130	0.11828	49°36′
.01	.19069	.07580	.55491	.19171	.76576	.88409	.3059	.11591	49 58
.02	.20630	.08146	.56689	.19504	.76987	.88642	.2989	.11358	50 21
.03	.22203	.08708	.57904	.19839	.77391	.88869	.2921	.11131	50 42
.04	.23788	.09268	.59134	.20176	.77789	.89092	.2855	.10908	51 04
1.05	1.25386	0.09825	1.60379	0.20515	0.78181	9.89310	1.2791	0.10690	51 26
.06	.26996	.10379	.61641	.20855	.78566	.89524	.2728	.10476	51 47
.07	.28619	.10930	.62919	.21197	.78946	.89733	.2667	.10267	52 08
.08	.30254	.11479	.64214	.21541	.79320	.89938	.2607	.10062	52 29
.09	.31903	.12025	.65525	.21886	.79688	.90139	.2549	.09861	52 50
1.10	1.33565	0.12569	1.66852	0.22233	0.80050	9.90336	1.2492	0.09664	53 11
.11	.35240	.13111	.68196	.22582	.80406	.90529	.2437	.09471	53 31
.12	.36929	.13649	.69557	.22931	.80757	.90718	.2383	.09282	53 52
.13	.38631	.14186	.70934	.23283	.81102	.90903	.2330	.09097	54 12
.14	.40347	.14720	.72329	.23636	.81441	.91085	.2279	.08915	54 32
1.15	1.42078	0.15253	1.73741	0.23990	0.81775	9.91262	1.2229	0.08738	54 52
.16	.43822	.15783	.75171	.24346	.82104	.91436	.2180	.08564	55 11
.17	.45581	.16311	.76618	.24703	.82427	.91607	.2132	.08393	55 31
.18	.47355	.16836	.78083	.25062	.82745	.91774	.2085	.08226	55 50
.19	.49143	.17360	.79565	.25422	.83058	.91938	.2040	.08062	56 09
1.20	1.50946	0.17882	1.81066	0.25784	0.83365	9.92099	1.1995	0.07901	56 29
.21	.52764	.18402	.82584	.26146	.83668	.92256	.1952	.07744	56 47
.22	.54598	.18920	.84121	.26510	.83965	.92410	.1910	.07590	57 06
.23	.56447	.19437	.85676	.26876	.84258	.92561	.1868	.07439	57 25
.24	.58311	.19951	.87250	.27242	.84546	.92709	.1828	.07291	57 43
1.25	1.60192	0.20464	1.88842	0.27610	0.84828	9.92854	1.1789	0.07146	58 02
.26	.62088	.20975	.90454	.27979	.85106	.92996	.1750	.07004	58 20
.27	.64001	.21485	.92084	.28349	.85380	.93135	.1712	.06865	58 38
.28	.65930	.21993	.93734	.28721	.85648	.93272	.1676	.06728	58 55
.29	.67876	.22499	.95403	.29093	.85913	.93406	.1640	.06594	59 13
1.30	1.69838	0.23004	1.97091	0.29467	0.86172	9.93537	1.1605	0.06463	59 31
.31	.71818	.23507	.98800	.29842	.86428	.93665	.1570	.06335	59 48
.32	.73814	.24009	2.00528	.30217	.86678	.93791	.1537	.06209	60 05
.33	.75828	.24509	.02276	.30594	.86925	.93914	.1504	.06086	60 22
.34	.77860	.25008	.04044	.30972	.87167	.94035	.1472	.05965	60 39
1.35	1.79909	0.25505	2.05833	0.31352	0.87405	9.94154	1.1441	0.05846	60 56
.36	.81977	.26002	.07643	.31732	.87639	.94270	.1410	.05730	61 13
.37	.84062	.26496	.09473	.32113	.87869	.94384	.1381	.05616	61 29
.38	.86166	.26990	.11324	.32495	.88095	.94495	.1351	.05505	61 45
.39	.88289	.27482	.13196	.32878	.88317	.94604	.1323	.05396	62 02
1.40	1.90430	0.27974	2.15090	0.33262	0.88535	9.94712	1.1295	0.05288	62 18
.41	.92591	.28464	.17005	.33647	.88749	.94817	.1268	.05183	62 34
.42	.94770	.28952	.18942	.34033	.88960	.94919	.1241	.05081	62 49
.43	.96970	.29440	.20900	.34420	.89167	.95020	.1215	.04980	63 05
.44	.99188	.29926	.22881	.34807	.89370	.95119	.1189	.04881	63 20
1.45	2.01427	0.30412	2.24884	0.35196	0.89569	9.95216	1.1165	0.04784	63 36
.46	.03686	.30896	.26910	.35585	.89765	.95311	.1140	.04689	63 51
.47	.05965	.31379	.28958	.35976	.89958	.95404	.1116	.04596	64 06
.48	.08265	.31862	.31029	.36367	.90147	.95495	.1093	.04505	64 21
.49	.10586	.32343	.33123	.36759	.90332	.95584	.1070	.04416	64 36
1.50	2.12928	0.32823	2.35241	0.37151	0.90515	9.95672	1.1048	0.04328	64 51

Table 16 (*continued*).
HYPERBOLIC FUNCTIONS.

u	sinh. u Nat.	sinh. u Log.	cosh. u Nat.	cosh. u Log.	tanh. u Nat.	tanh. u Log.	coth. u Nat.	coth. u Log.	gd. u
1.50	2.12928	0.32823	2.35241	0.37151	0.90515	9.95672	1.1048	0.04328	64° 51′
.51	.15291	.33303	.37382	.37545	.90694	.95758	.1026	.04242	65 05
.52	.17676	.33781	.39547	.37939	.90870	.95842	.1005	.04158	65 20
.53	.20082	.34258	.41736	.38334	.91042	.95924	.0984	.04076	65 34
.54	.22510	.34735	.43949	.38730	.91212	.96005	.0963	.03995	65 48
1.55	2.24961	0.35211	2.46186	0.39126	0.91379	9.96084	1.0943	0.03916	66 02
.56	.27434	.35686	.48448	.39524	.91542	.96162	.0924	.03838	66 16
.57	.29930	.36160	.50735	.39921	.91703	.96238	.0905	.03762	66 30
.58	.32449	.36633	.53047	.40320	.91860	.96313	.0886	.03687	66 43
.59	.34991	.37105	.55384	.40719	.92015	.96386	.0868	.03614	66 57
1.60	2.37557	0.37577	2.57746	0.41119	0.92167	9.96457	1.0850	0.03543	67 10
.61	40146	.38048	.60135	.41520	.92316	.96528	.0832	.03472	67 24
.62	.42760	.38518	.62549	.41921	.92462	.96597	.0815	.03403	67 37
.63	.45397	.38987	.64990	.42323	.92606	.96664	.0798	.03336	67 50
.64	.48059	.39456	.67457	.42725	.92747	.96730	.0782	.03270	68 03
1.65	2.50746	0.39923	2.69951	0.43129	0.92886	9.96795	1.0766	0.03205	68 15
.66	.53459	.40391	.72472	.43532	.93022	.96858	.0750	.03142	68 28
.67	.56196	.40857	.75021	.43937	.93155	.96921	.0735	.03079	68 41
.68	.58959	.41323	.77596	.44341	.93286	.96982	.0720	.03018	68 53
.69	.61748	.41788	.80200	.44747	.93415	.97042	.0705	.02958	69 05
1.70	2.64563	0.42253	2.82832	0.45153	0.93541	9.97100	1.0691	0.02900	69 18
.71	.67405	.42717	.85491	.45559	.93665	.97158	.0676	.02842	69 30
.72	.70273	.43180	.88180	.45966	.93786	.97214	.0663	.02786	69 42
.73	.73168	.43643	.90897	.46374	.93906	.97269	.0649	.02731	69 54
.74	.76091	.44105	.93643	.46782	.94023	.97323	.0636	.02677	70 05
1.75	2.79041	0.44567	2.96419	0.47191	0.94138	9.97376	1.0623	0.02624	70 17
.76	.82020	.45028	.99224	.47600	.94250	.97428	.0610	.02572	70 29
.77	.85026	.45488	3.02059	.48009	.94361	.97479	.0598	.02521	70 40
.78	.88061	.45948	.04925	.48419	.94470	.97529	.0585	.02471	70 51
.79	.91125	.46408	.07821	.48830	.94576	.97578	.0574	.02422	71 03
1.80	2.94217	0.46867	3.10747	0.49241	0.94681	9.97626	1.0562	0.02374	71 14
.81	.97340	.47325	.13705	.49652	.94783	.97673	.0550	.02327	71 25
.82	3.00492	.47783	.16694	.50064	.94884	.97719	.0539	.02281	71 36
.83	.03674	.48241	.19715	.50476	.94983	.97764	.0528	.02236	71 46
.84	.06886	.48698	.22768	.50889	.95080	.97809	.0518	.02191	71 57
1.85	3.10129	0.49154	3.25853	0.51302	0.95175	9.97852	1.0507	0.02148	72 08
.86	.13403	.49610	.28970	.51716	.95268	.97895	.0497	.02105	72 18
.87	.16709	.50066	.32121	.52130	.95359	.97936	.0487	.02064	72 29
.88	.20046	.50521	.35305	.52544	.95449	.97977	.0477	.02023	72 39
.89	.23415	.50976	.38522	.52959	.95537	.98017	.0467	.01983	72 49
1.90	3.26816	0.51430	3.41773	0.53374	0.95624	9.98057	1.0458	0.01943	72 59
.91	.30250	.51884	.45058	.53789	.95709	.98095	.0448	.01905	73 09
.92	.33718	.52338	.48378	.54205	.95792	.98133	.0439	.01867	73 19
.93	.37218	.52791	.51733	.54621	.95873	.98170	.0430	.01830	73 29
.94	.40752	.53244	.55123	.55038	.95953	.98206	.0422	.01794	73 39
1.95	3.44321	0.53696	3.58548	0.55455	0.96032	9.98242	1.0413	0.01758	73 48
.96	.47923	.54148	.62009	.55872	.96109	.98276	.0405	.01724	73 58
.97	.51561	.54600	.65507	.56290	.96185	.98311	.0397	.01689	74 07
.98	.55234	.55051	.69041	.56707	.96259	.98344	.0389	.01656	74 17
.99	.58942	.55502	.72611	.57126	.96331	.98377	.0381	.01623	74 26
2.00	3.62686	0.55953	3.76220	0.57544	0.96403	9.98409	1.0373	0.01591	74 35

HYPERBOLIC FUNCTIONS.

u	sinh. u		cosh. u		tanh. u		coth. u.		gd. u
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
2.00	3.62686	0.55953	3.76220	0.57544	0.96403	9.98409	1.0373	0.01591	74° 35′
.01	.66466	.56403	.79865	.57963	.96473	.98440	.0366	.01560	74 44
.02	.70283	.56853	.83549	.58382	.96541	.98471	.0358	.01529	74 53
.03	.74138	.57303	.87271	.58802	.96609	.98502	.0351	.01498	75 02
.04	.78029	.57753	.91032	.59221	.96675	.98531	.0344	.01469	75 11
2.05	3.81958	0.58202	3.94832	0.59641	0.96740	9.98560	1.0337	0.01440	75 20
.06	.85926	.58650	.98671	.60061	.96803	.98589	.0330	.01411	75 28
.07	.89932	.59099	4.02550	.60482	.96865	.98617	.0324	.01383	75 37
.08	.93977	.59547	.06470	.60903	.96926	.98644	.0317	.01356	75 45
.09	.98061	.59995	.10430	.61324	.96986	.98671	.0311	.01329	75 54
2.10	4.02186	0.60443	4.14431	0.61745	0.97045	9.98697	1.0304	0.01303	76 02
.11	.06350	.60890	.18474	.62167	.97103	.98723	.0298	.01277	76 10
.12	.10555	.61337	.22558	.62589	.97159	.98748	.0292	.01252	76 19
.13	.14801	.61784	.26685	.63011	.97215	.98773	.0286	.01227	76 27
.14	.19089	.62231	.30855	.63433	.97269	.98798	.0281	.01202	76 35
2.15	4.23419	0.62677	4.35067	0.63856	0.97323	9.98821	1.0275	0.01179	76 43
.16	.27791	.63123	.39323	.64278	.97375	.98845	.0270	.01155	76 51
	.32205	.63569	.43623	.64701	.97426	.98868	.0264	.01132	76 58
.18	.36663	.64015	.47967	.65125	.97477	.98890	.0259	.01110	77 06
.19	.41165	.64460	.52356	.65548	.97526	.98912	.0254	.01088	77 14
2.20	4.45711	0.64905	4.56791	0.65972	0.97574	9.98934	1.0249	0.01066	77 21
.21	.50301	.65350	.61271	.66396	.97622	.98955	.0244	.01045	77 29
.22	.54936	.65795	.65797	.66820	.97668	.98975	.0239	.01025	77 36
.23	.59617	.66240	.70370	.67244	.97714	.98996	.0234	.01004	77 44
.24	.64344	.66684	.74989	.67668	.97759	.99016	.0229	.00984	77 51
2.25	4.69117	0.67128	4.79657	0.68093	0.97803	9.99035	1.0225	0.00965	77 58
.26	.73937	.67572	.84372	.68518	.97846	.99054	.0220	.00946	78 05
.27	.78804	.68016	.89136	.68943	.97888	.99073	.0216	.00927	78 12
.28	.83720	.68459	.93948	.69368	.97929	.99091	.0211	.00909	78 19
.29	.88684	.68903	.98810	.69794	.97970	.99109	.0207	.00891	78 26
2.30	4.93696	0.69346	5.03722	0.70219	0.98010	9.99127	1.0203	0.00873	78 33
.31	.98758	.69789	.08684	.70645	.98049	.99144	.0199	.00856	78 40
.32	5.03870	.70232	.13697	.71071	.98087	.99161	.0195	.00839	78 46
.33	.09032	.70675	.18762	.71497	.98124	.99178	.0191	.00822	78 53
.34	.14245	.71117	.23878	.71923	.98161	.99194	.0187	.00806	79 00
2.35	5.19510	0.71559	5.29047	0.72349	0.98197	9.99210	1.0184	0.00790	79 06
.36	.24827	.72002	.34269	.72776	.98233	.99226	.0180	.00774	79 13
.37	.30196	.72444	.39544	.73203	.98267	.99241	.0176	.00759	79 19
.38	.35618	.72885	.44873	.73630	.98301	.99256	.0173	.00744	79 25
.39	.41093	.73327	.50256	.74056	.98335	.99271	.0169	.00729	79 32
2.40	5.46623	0.73769	5.55695	0.74484	0.98367	9.99285	1.0166	0.00715	79 38
.41	.52207	.74210	.61189	.74911	.98400	.99299	.0163	.00701	79 44
.42	.57847	.74652	.66739	.75338	.98431	.99313	.0159	.00687	79 50
.43	.63542	.75093	.72346	.75766	.98462	.99327	.0156	.00673	79 56
.44	.69294	.75534	.78010	.76194	.98492	.99340	.0153	.00660	80 02
2.45	5.75103	0.75975	5.83732	0.76621	0.98522	9.99353	1.0150	0.00647	80 08
.46	.80969	.76415	.89512	.77049	.98551	.99366	.0147	.00634	80 14
.47	.86893	.76856	.95352	.77477	.98579	.99379	.0144	.00621	80 20
.48	.92876	.77296	6.01250	.77906	.98607	.99391	.0141	.00609	80 26
.49	.98918	.77737	.07209	.78334	.98635	.99403	.0138	.00597	80 31
2.50	6.05020	0.78177	6.13229	0.78762	0.98661	9.99415	1.0136	0.00585	80 37

HYPERBOLIC FUNCTIONS.

u	sinh. u		cosh. u		tanh. u		coth. u		gd. u
	Nat.	Log.	Nat.	Log.	Nat.	Log.	Nat.	Log.	
2.50	6.05020	0.78177	6.13229	0.78762	0.98661	9.99415	1.0136	0.00585	80° 37′
.51	.11183	.78617	.19310	.79191	.98688	.99426	.0133	.00574	80 42
.52	.17407	.79057	.25453	.79619	.98714	.99438	.0130	.00562	80 48
.53	.23692	.79497	.31658	.80048	.98739	.99449	.0128	.00551	80 53
.54	.30040	.79937	.37927	.80477	.98764	.99460	.0125	.00540	80 59
2.55	6.36451	0.80377	6.44259	0.80906	0.98788	9.99470	1.0123	0.00530	81 04
.56	.42926	.80816	.50656	.81335	.98812	.99481	.0120	.00519	81 10
.57	.49464	.81256	.57118	.81764	.98835	.99491	.0118	.00509	81 15
.58	.56068	.81695	.63646	.82194	.98858	.99501	.0115	.00499	81 20
.59	.62738	.82134	.70240	.82623	.98881	.99511	.0113	.00489	81 25
2.60	6.69473	0.82573	6.76901	0.83052	0.98903	9.99521	1.0111	0.00479	81 30
.61	.76276	.83012	.83629	.83482	.98924	.99530	.0109	.00470	81 35
.62	.83146	.83451	.90426	.83912	.98946	.99540	.0107	.00460	81 40
.63	.90085	.83890	.97292	.84341	.98966	.99549	.0104	.00451	81 45
.64	.97092	.84329	7.04228	.84771	.98987	.99558	.0102	.00442	81 50
2.65	7.04169	0.84768	7.11234	0.85201	0.99007	9.99566	1.0100	0.00434	81 55
.66	.11317	.85206	.18312	.85631	.99026	.99575	.0098	.00425	82 00
.67	.18536	.85645	.25461	.86061	.99045	.99583	.0096	.00417	82 05
.68	.25827	.86083	.32683	.86492	.99064	.99592	.0094	.00408	82 09
.69	.33190	.86522	.39978	.86922	.99083	.99600	.0093	.00400	82 14
2.70	7.40626	0.86960	7.47347	0.87352	0.99101	9.99608	1.0091	0.00392	82 19
.71	.48137	.87398	.54791	.87783	.99118	.99615	.0089	.00385	82 23
.72	.55722	.87836	.62310	.88213	.99136	.99623	.0087	.00377	82 28
.73	.63383	.88274	.69905	.88644	.99153	.99631	.0085	.00369	82 32
.74	.71121	.88712	.77578	.89074	.99170	.99638	.0084	.00362	82 37
2.75	7.78935	0.89150	7.85328	0.89505	0.99186	9.99645	1.0082	0.00355	82 41
.76	.86828	.89588	.93157	.89936	.99202	.99652	.0080	.00348	82 45
.77	.94799	.90026	8.01065	.90367	.99218	.99659	.0079	.00341	82 50
.78	8.02849	.90463	.09053	.90798	.99233	.99666	.0077	.00334	82 54
.79	.10980	.90901	.17122	.91229	.99248	.99672	.0076	.00328	82 58
2.80	8.19192	0.91339	8.25273	0.91660	0.99263	9.99679	1.0074	0.00321	83 02
.81	.27486	.91776	.33506	.92091	.99278	.99685	.0073	.00315	83 07
.82	.35862	.92213	.41823	.92522	.99292	.99691	.0071	.00309	83 11
.83	.44322	.92651	.50224	.92953	.99306	.99698	.0070	.00302	83 15
.84	.52867	.93088	.58710	.93385	.99320	.99704	.0069	.00296	83 19
2.85	8.61497	0.93525	8.67281	0.93816	0.99333	9.99709	1.0067	0.00291	83 23
.86	.70213	.93963	.75940	.94247	.99346	.99715	.0066	.00285	83 27
.87	.79016	.94400	.84686	.94679	.99359	.99721	.0065	.00279	83 31
.88	.87907	.94837	.93520	.95110	.99372	.99726	.0063	.00274	83 34
.89	.96887	.95274	9.02444	.95542	.99384	.99732	.0062	.00268	83 38
2.90	9.05956	0.95711	9.11458	0.95974	0.99396	9.99737	1.0061	0.00263	83 42
.91	.15116	.96148	.20564	.96405	.99408	.99742	.0060	.00258	83 46
.92	.24368	.96584	.29761	.96837	.99420	.99747	.0058	.00253	83 50
.93	.33712	.97021	.39051	.97269	.99531	.99752	.0057	.00248	83 53
.94	.43149	.97458	.48436	.97701	.99443	.99757	.0056	.00243	83 57
2.95	9.52681	0.97895	9.57915	0.98133	0.99454	9.99762	1.0055	0.00238	84 00
.96	.62308	.98331	.67490	.98565	.99464	.99767	.0054	.00233	84 04
.97	.72031	.98768	.77161	.98997	.99475	.99771	.0053	.00229	84 08
.98	.81851	.99205	.86930	.99429	.99485	.99776	.0052	.00224	84 11
.99	.91770	.99641	.96798	.99861	.99496	.99780	.0051	.00220	84 15
3.00	10.01787	1.00078	10.06766	1.00293	0.99505	9.99785	1.0050	0.00215	84 18

TABLE 16 (*continued*).

HYPERBOLIC FUNCTIONS.

u	sinh. u Nat.	sinh. u Log.	cosh. u Nat.	cosh. u Log.	tanh. u Nat.	tanh. u Log.	coth. u Nat.	coth. u Log.	gd. u
3.0	10.0179	1.00078	10.0677	1.00293	0.99505	9.99785	1.0050	0.00215	84°18′
.1	11.0765	.04440	11.1215	.04616	.99595	.99824	.0041	.00176	84 50
.2	12.2459	.08799	12.2866	.08943	.99668	.99856	.0033	.00144	85 20
.3	13.5379	.13155	13.5748	.13273	.99728	.99882	.0027	.00118	85 47
.4	14.9654	.17509	14.9987	.17605	.99777	.99903	.0022	.00097	86 11
3.5	16.5426	1.21860	16.5728	1.21940	0.99818	9.99921	1.0018	0.00079	86 32
.6	18.2855	.26211	18.3128	.26275	.99851	.99935	.0015	.00065	86 52
.7	20.2113	.30559	20.2360	.30612	.99878	.99947	.0012	.00053	87 10
.8	22.3394	.34907	22.3618	.34951	.99900	.99957	.0010	.00043	87 26
.9	24.6911	.39254	24.7113	.39290	.99918	.99964	.0008	.00036	87 41
4.0	27.2899	1.43600	27.3082	1.43629	0.99933	9.99971	1.0007	0.00029	87 54
.1	30.1619	.47946	30.1784	.47970	.99945	.99976	.0005	.00024	88 06
.2	33.3357	.52291	33.3507	.52310	.99955	.99980	.0004	.00020	88 17
.3	36.8431	.56636	36.8567	.56652	.99963	.99984	.0004	.00016	88 27
.4	40.7193	.60980	40.7316	.60993	.99970	.99987	.0003	.00013	88 36
4.5	45.0030	1.65324	45.0141	1.65335	0.99975	9.99989	1.0002	0.00011	88 44
.6	49.7371	.69668	49.7472	.69677	.99980	.99991	.0002	.00009	88 51
.7	54.9690	.74012	54.9781	.74019	.99983	.99993	.0002	.00007	88 57
.8	60.7511	.78355	60.7593	.78361	.99986	.99994	.0001	.00006	89 03
.9	67.1412	.82699	67.1486	.82704	.99989	.99995	.0001	.00005	89 09
5.0	74.2032	1.87042	74.2099	1.87046	0.99991	9.99996	1.0001	0.00004	89 14

Table 17. Factorials.

See table 15 for logarithms of the products 1.2.3. . . . *n* from 1 to 100.
See table 31 for log. (*n*+*1*) for values of *n* between 1.000 and 2.000.

n	$\frac{1}{n:}$	*n*: = 1. 2. 3. 4 . . . *n*	*n*
1	1.	1	1
2	0.5	2	2
3	.16666 66666 66666 66666 66667	6	3
4	.04166 66666 66666 66666 66667	24	4
5	.00833 33333 33333 33333 33333	120	5
6	0.00138 88888 88888 88888 88889	720	6
7	.00019 84126 98412 69841 26984	5040	7
8	.00002 48015 87301 58730 15873	40320	8
9	.00000 27557 31922 39858 90653	3 62880	9
10	.00000 02755 73192 23985 89065	36 28800	10
11	0.00000 00250 52108 38544 17188	399 16800	11
12	.00000 00020 87675 69878 68099	4790 01600	12
13	.00000 00001 60590 43836 82161	62270 20800	13
14	.00000 00000 11470 74559 77297	8 71782 91200	14
15	.00000 00000 00764 71637 31820	130 76743 68000	15
16	0.00000 00000 00047 79477 33239	2092 27898 88000	16
17	.00000 00000 00002 81145 72543	35568 74280 96000	17
18	.00000 00000 00000 15619 20697	6 40237 37057 28000	18
19	.00000 00000 00000 00822 06352	121 64510 04088 32000	19
20	.00000 00000 00000 00041 10318	2432 90200 81766 40000	20

TABLE 18.

EXPONENTIAL FUNCTION.

x	log₁₀(eˣ)	eˣ	e⁻ˣ	x	log₁₀(eˣ)	eˣ	e⁻ˣ
0.00	0.00000	1.0000	1.000000	0.50	0.21715	1.6487	0.606531
.01	.00434	.0101	0.990050	.51	.22149	.6653	.600496
.02	.00869	.0202	.980199	.52	.22583	.6820	.594521
.03	.01303	.0305	.970446	.53	.23018	.6989	.588605
.04	.01737	.0408	.960789	.54	.23452	.7160	.582748
0.05	0.02171	1.0513	0.951229	0.55	0.23886	1.7333	0.576950
.06	.02606	.0618	.941765	.56	.24320	.7507	.571209
.07	.03040	.0725	.932394	.57	.24755	.7683	.565525
.08	.03474	.0833	.923116	.58	.25189	.7860	.559898
.09	.03909	.0942	.913931	.59	.25623	.8040	.554327
0.10	0.04343	1.1052	0.904837	0.60	0.26058	1.8221	0.548812
.11	.04777	.1163	.895834	.61	.26492	.8404	.543351
.12	.05212	.1275	.886920	.62	.26926	.8589	.537944
.13	.05646	.1388	.878095	.63	.27361	.8776	.532592
.14	.06080	.1503	.869358	.64	.27795	.8965	.527292
0.15	0.06514	1.1618	0.860708	0.65	0.28229	1.9155	0.522046
.16	.06949	.1735	.852144	.66	.28663	.9348	.516851
.17	.07383	.1853	.843665	.67	.29098	.9542	.511709
.18	.07817	.1972	.835270	.68	.29532	.9739	.506617
.19	.08252	.2092	.826959	.69	.29966	.9937	.501576
0.20	0.08686	1.2214	0.818731	0.70	0.30401	2.0138	0.496585
.21	.09120	.2337	.810584	.71	.30835	.0340	.491644
.22	.09554	.2461	.802519	.72	.31269	.0544	.486752
.23	.09989	.2586	.794534	.73	.31703	.0751	.481909
.24	.10423	.2712	.786628	.74	.32138	.0959	.477114
0.25	0.10857	1.2840	0.778801	0.75	0.32572	2.1170	0.472367
.26	.11292	.2969	.771052	.76	.33006	.1383	.467666
.27	.11726	.3100	.763379	.77	.33441	.1598	.463013
.28	.12160	.3231	.755784	.78	.33875	.1815	.458406
.29	.12595	.3364	.748264	.79	.34309	.2034	.453845
0.30	0.13029	1.3499	0.740818	0.80	0.34744	2.2255	0.449329
.31	.13463	.3634	.733447	.81	.35178	.2479	.444858
.32	.13897	.3771	.726149	.82	.35612	.2705	.440432
.33	.14332	.3910	.718924	.83	.36046	.2933	.436049
.34	.14766	.4049	.711770	.84	.36481	.3164	.431711
0.35	0.15200	1.4191	0.704688	0.85	0.36915	2.3396	0.427415
.36	.15635	.4333	.697676	.86	.37349	.3632	.423162
.37	.16069	.4477	.690734	.87	.37784	.3869	.418952
.38	.16503	.4623	.683861	.88	.38218	.4109	.414783
.39	.16937	.4770	.677057	.89	.38652	.4351	.410656
0.40	0.17372	1.4918	0.670320	0.90	0.39087	2.4596	0.406570
.41	.17806	.5068	.663650	.91	.39521	.4843	.402524
.42	.18240	.5220	.657047	.92	.39955	.5093	.398519
.43	.18675	.5373	.650509	.93	.40389	.5345	.394554
.44	.19109	.5527	.644036	.94	.40824	.5600	.390628
0.45	0.19543	1.5683	0.637628	0.95	0.41258	2.5857	0.386741
.46	.19978	.5841	.631284	.96	.41692	.6117	.382893
.47	.20412	.6000	.625002	.97	.42127	.6379	.379083
.48	.20846	.6161	.618783	.98	.42561	.6645	.375311
.49	.21280	.6323	.612626	.99	.42995	.6912	.371577
0.50	0.21715	1.6487	0.606531	1.00	0.43429	2.7183	0.367879

EXPONENTIAL FUNCTION.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
1.00	0.43429	2.7183	0.367879	1.50	0.65144	4.4817	0.223130
.01	.43864	.7456	.364219	.51	.65578	.5267	.220910
.02	.44298	.7732	.360595	.52	.66013	.5722	.218712
.03	.44732	.8011	.357007	.53	.66447	.6182	.216536
.04	.45167	.8292	.353455	.54	.66881	.6646	.214381
1.05	0.45601	2.8577	0.349938	1.55	0.67316	4.7115	0.212248
.06	.46035	.8864	.346456	.56	.67750	.7588	.210136
.07	.46470	.9154	.343009	.57	.68184	.8066	.208045
.08	.46904	.9447	.339596	.58	.68619	.8550	.205975
.09	.47338	.9743	.336216	.59	.69053	.9037	.203926
1.10	0.47772	3.0042	0.332871	1.60	0.69487	4.9530	0.201897
.11	.48207	.0344	.329559	.61	.69921	5.0028	.199888
.12	.48641	.0649	.326280	.62	.70356	.0531	.197899
.13	.49075	.0957	.323033	.63	.70790	.1039	.195930
.14	.49510	.1268	.319819	.64	.71224	.1552	.193980
1.15	0.49944	3.1582	0.316637	1.65	0.71659	5.2070	0.192050
.16	.50378	.1899	.313486	.66	.72093	.2593	.190139
.17	.50812	.2220	.310367	.67	.72527	.3122	.188247
.18	.51247	.2544	.307279	.68	.72961	.3656	.186374
.19	.51681	.2871	.304221	.69	.73396	.4195	.184520
1.20	0.52115	3.3201	0.301194	1.70	0.73830	5.4739	0.182684
.21	.52550	.3535	.298197	.71	.74264	.5290	.180866
.22	.52984	.3872	.295230	.72	.74699	.5845	.179066
.23	.53418	.4212	.292293	.73	.75133	.6407	.177284
.24	.53853	.4556	.289384	.74	.75567	.6973	.175520
1.25	0.54287	3.4903	0.286505	1.75	0.76002	5.7546	0.173774
.26	.54721	.5254	.283654	.76	.76436	.8124	.172045
.27	.55155	.5609	.280832	.77	.76870	.8709	.170333
.28	.55590	.5966	.278037	.78	.77304	.9299	.168638
.29	.56024	.6328	.275271	.79	.77739	.9895	.166960
1.30	0.56458	3.6693	0.272532	1.80	0.78173	6.0496	0.165299
.31	.56893	.7062	.269820	.81	.78607	.1104	.163654
.32	.57327	.7434	.267135	.82	.79042	.1719	.162026
.33	.57761	.7810	.264477	.83	.79476	.2339	.160414
.34	.58195	.8190	.261846	.84	.79910	.2965	.158817
1.35	0.58630	3.8574	0.259240	1.85	0.80344	6.3598	0.157237
.36	.59064	.8962	.256661	.86	.80779	.4237	.155673
.37	.59498	.9354	.254107	.87	.81213	.4883	.154124
.38	.59933	.9749	.251579	.88	.81647	.5535	.152590
.39	.60367	4.0149	.249075	.89	.82082	.6194	.151072
1.40	0.60801	4.0552	0.246597	1.90	0.82516	6.6859	0.149569
.41	.61236	.0960	.244143	.91	.82950	.7531	.148080
.42	.61670	.1371	.241714	.92	.83385	.8210	.146607
.43	.62104	.1787	.239309	.93	.83819	.8895	.145148
.44	.62538	.2207	.236928	.94	.84253	.9588	.143704
1.45	0.62973	4.2631	0.234570	1.95	0.84687	7.0287	0.142274
.46	.63407	.3060	.232236	.96	.85122	.0993	.140858
.47	.63841	.3492	.229925	.97	.85556	.1707	.139457
.48	.64276	.3929	.227638	.98	.85990	.2427	.138069
.49	.64710	.4371	.225373	.99	.86425	.3155	.136695
1.50	0.65144	4.4817	0.223130	2.00	0.86859	7.3891	0.135335

EXPONENTIAL FUNCTION.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
2.00	0.86859	7.3891	0.135335	2.50	1.08574	12.182	0.082085
.01	.87293	.4633	.133989	.51	.09008	.305	.081268
.02	.87727	.5383	.132655	.52	.09442	.429	.080460
.03	.88162	.6141	.131336	.53	.09877	.554	.079659
.04	.88596	.6906	.130029	.54	.10311	.680	.078866
2.05	0.89030	7.7679	0.128735	2.55	1.10745	12.807	0.078082
.06	.89465	.8460	.127454	.56	.11179	.936	.077305
.07	.89899	.9248	.126186	.57	.11614	13.066	.076536
.08	.90333	8.0045	.124930	.58	.12048	.197	.075774
.09	.90768	.0849	.123687	.59	.12482	.330	.075020
2.10	0.91202	8.1662	0.122456	2.60	1.12917	13.464	0.074274
.11	.91636	.2482	.121238	.61	.13351	.599	.073535
.12	.92070	.3311	.120032	.62	.13785	.736	.072803
.13	.92505	.4149	.118837	.63	.14219	.874	.072078
.14	.92939	.4994	.117655	.64	.14654	14.013	.071361
2.15	0.93373	8.5849	0.116484	2.65	1.15088	14.154	0.070651
.16	.93808	.6711	.115325	.66	.15522	.296	.069948
.17	.94242	.7583	.114178	.67	.15957	.440	.069252
.18	.94676	.8463	.113042	.68	.16391	.585	.068563
.19	.95110	.9352	.111917	.69	.16825	.732	.067881
2.20	0.95545	9.0250	0.110803	2.70	1.17260	14.880	0.067206
.21	.95979	.1157	.109701	.71	.17694	15.029	.066537
.22	.96413	.2073	.108609	.72	.18128	.180	.065875
.23	.96848	.2999	.107528	.73	.18562	.333	.065219
.24	.97282	.3933	.106459	.74	.18997	.487	.064570
2.25	0.97716	9.4877	0.105399	2.75	1.19431	15.643	0.063928
.26	.98151	.5831	.104350	.76	.19865	.800	.063292
.27	.98585	.6794	.103312	.77	.20300	.959	.062662
.28	.99019	.7767	.102284	.78	.20734	16.119	.062039
.29	.99453	.8749	.101266	.79	.21168	.281	.061421
2.30	0.99888	9.9742	0.100259	2.80	1.21602	16.445	0.060810
.31	1.00322	10.074	.099261	.81	.22037	.610	.060205
.32	.00756	.176	.098274	.82	.22471	.777	.059606
.33	.01191	.278	.097296	.83	.22905	.945	.059013
.34	.01625	.381	.096328	.84	.23340	17.116	.058426
2.35	1.02059	10.486	0.095369	2.85	1.23774	17.288	0.057844
.36	.02493	.591	.094420	.86	.24208	.462	.057269
.37	.02928	.697	.093481	.87	.24643	.637	.056699
.38	.03362	.805	.092551	.88	.25077	.814	.056135
.39	.03796	.913	.091630	.89	.25511	.993	.055576
2.40	1.04231	11.023	0.090718	2.90	1.25945	18.174	0.055023
.41	.04665	.134	.089815	.91	.26380	.357	.054476
.42	.05099	.246	.088922	.92	.26814	.541	.053934
.43	.05534	.359	.088037	.93	.27248	.728	.053397
.44	.05968	.473	.087161	.94	.27683	.916	.052866
2.45	1.06402	11.588	0.086294	2.95	1.28117	19.106	0.052340
.46	.06836	.705	.085435	.96	.28551	.298	.051819
.47	.07271	.822	.084585	.97	.28985	.492	.051303
.48	.07705	.941	.083743	.98	.29420	.688	.050793
.49	.08139	12.061	.082910	.99	.29854	.886	.050287
2.50	1.08574	12.182	0.082085	3.00	1.30288	20.086	0.049787

EXPONENTIAL FUNCTION.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
3.00	1.30288	20.086	0.049787	3.50	1.52003	33.115	0.030197
.01	.30723	.287	.049292	.51	.52437	.448	.029897
.02	.31157	.491	.048801	.52	.52872	.784	.029599
.03	.31591	.697	.048316	.53	.53306	34.124	.029305
.04	.32026	.905	.047835	.54	.53740	.467	.029013
3.05	1.32460	21.115	0.047359	3.55	1.54175	34.813	0.028725
.06	.32894	.328	.046888	.56	.54609	35.163	.028439
.07	.33328	.542	.046421	.57	.55043	.517	.028156
.08	.33763	.758	.045959	.58	.55477	.874	.027876
.09	.34197	.977	.045502	.59	.55912	36.234	.027598
3.10	1.34631	22.198	0.045049	3.60	1.56346	36.598	0.027324
.11	.35066	.421	.044601	.61	.56780	.966	.027052
.12	.35500	.646	.044157	.62	.57215	37.338	.026783
.13	.35934	.874	.043718	.63	.57649	.713	.026516
.14	.36368	23.104	.043283	.64	.58083	38.092	.026252
3.15	1.36803	23.336	0.042852	3.65	1.58517	38.475	0.025991
.16	.37237	.571	.042426	.66	.58952	.861	.025733
.17	.37671	.807	.042004	.67	.59386	39.252	.025476
.18	.38106	24.047	.041586	.68	.59820	.646	.025223
.19	.38540	.288	.041172	.69	.60255	40.045	.024972
3.20	1.38974	24.533	0.040762	3.70	1.60689	40.447	0.024724
.21	.39409	.779	.040357	.71	.61123	.854	.024478
.22	.39843	25.028	.039955	.72	.61558	41.264	.024234
.23	.40277	.280	.039557	.73	.61992	.679	.023993
.24	.40711	.534	.039164	.74	.62426	42.098	.023754
3.25	1.41146	25.790	0.038774	3.75	1.62860	42.521	0.023518
.26	.41580	26.050	.038388	.76	.63295	.948	.023284
.27	.42014	.311	.038006	.77	.63729	43.380	.023052
.28	.42449	.576	.037628	.78	.64163	.816	.022823
.29	.42883	.843	.037254	.79	.64598	44.256	.022596
3.30	1.43317	27.113	0.036883	3.80	1.65032	44.701	0.022371
.31	.43751	.385	.036516	.81	.65466	45.150	.022148
.32	.44186	.660	.036153	.82	.65900	.604	.021928
.33	.44620	.938	.035793	.83	.66335	46.063	.021710
.34	.45054	28.219	.035437	.84	.66769	.525	.021494
3.35	1.45489	28.503	0.035084	3.85	1.67203	46.993	0.021280
.36	.45923	.789	.034735	.86	.67638	47.465	.021068
.37	.46357	29.079	.034390	.87	.68072	.942	.020858
.38	.46792	.371	.034047	.88	.68506	48.424	.020651
.39	.47226	.666	.033709	.89	.68941	.911	.020445
3.40	1.47660	29.964	0.033373	3.90	1.69375	49.402	0.020242
.41	.48094	30.265	.033041	.91	.69809	.899	.020041
.42	.48529	.569	.032712	.92	.70243	50.400	.019841
.43	.48963	.877	.032387	.93	.70678	.907	.019644
.44	.49397	31.187	.032065	.94	.71112	51.419	.019448
3.45	1.49832	31.500	0.031746	3.95	1.71546	51.935	0.019255
.46	.50266	.817	.031430	.96	.71981	52.457	.019063
.47	.50700	32.137	.031117	.97	.72415	.985	.018873
.48	.51134	.460	.030807	.98	.72849	53.517	.018686
.49	.51569	.786	.030501	.99	.73283	54.055	.018500
3.50	1.52003	33.115	0.030197	4.00	1.73718	54.598	0.018316

EXPONENTIAL FUNCTION.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
4.00	1.73718	54.598	0.018316	4.50	1.95433	90.017	0.011109
.01	.74152	55.147	.018133	.51	.95867	.922	.010998
.02	.74586	.701	.017953	.52	.96301	91.836	.010889
.03	.75021	56.261	.017774	.53	.96735	92.759	.010781
.04	.75455	.826	.017597	.54	.97170	93.691	.010673
4.05	1.75889	57.397	0.017422	4.55	1.97604	94.632	0.010567
.06	.76324	.974	.017249	.56	.98038	95.583	.010462
.07	.76758	58.557	.017077	.57	.98473	96.544	.010358
.08	.77192	59.145	.016907	.58	.98907	97.514	.010255
.09	.77626	.740	.016739	.59	.99341	98.494	.010153
4.10	1.78061	60.340	0.016573	4.60	1.99775	99.484	0.010052
.11	.78495	.947	.016408	.61	2.00210	100.48	.009952
.12	.78929	61.559	.016245	.62	.00644	101.49	.009853
.13	.79364	62.178	.016083	.63	.01078	102.51	.009755
.14	.79798	.803	.015923	.64	.01513	103.54	.009658
4.15	1.80232	63.434	0.015764	4.65	2.01947	104.58	0.009562
.16	.80667	64.072	.015608	.66	.02381	105.64	.009466
.17	.81101	.715	.015452	.67	.02816	106.70	.009372
.18	.81535	65.366	.015299	.68	.03250	107.77	.009279
.19	.81969	66.023	.015146	.69	.03684	108.85	.009187
4.20	1.82404	66.686	0.014996	4.70	2.04118	109.95	0.009095
.21	.82838	67.357	.014846	.71	.04553	111.05	.009005
.22	.83272	68.033	.014699	.72	.04987	112.17	.008915
.23	.83707	.717	.014552	.73	.05421	113.30	.008826
.24	.84141	69.408	.014408	.74	.05856	114.43	.008739
4.25	1.84575	70.105	0.014264	4.75	2.06290	115.58	0.008652
.26	.85009	.810	.014122	.76	.06724	116.75	.008566
.27	.85444	71.522	.013982	.77	.07158	117.92	.008480
.28	.85878	72.240	.013843	.78	.07593	119.10	.008396
.29	.86312	.966	.013705	.79	.08027	120.30	.008312
4.30	1.86747	73.700	0.013569	4.80	2.08461	121.51	0.008230
.31	.87181	74.440	.013434	.81	.08896	122.73	.008148
.32	.87615	75.189	.013300	.82	.09330	123.97	.008067
.33	.88050	.944	.013168	.83	.09764	125.21	.007987
.34	.88484	76.708	.013037	.84	.10199	126.47	.007907
4.35	1.88918	77.478	0.012907	4.85	2.10633	127.74	0.007828
.36	.89352	78.257	.012778	.86	.11067	129.02	.007750
.37	.89787	79.044	.012651	.87	.11501	130.32	.007673
.38	.90221	79.838	.012525	.88	.11936	131.63	.007597
.39	.90655	80.640	.012401	.89	.12370	132.95	.007521
4.40	1.91090	81.451	0.012277	4.90	2.12804	134.29	0.007447
.41	.91524	82.269	.012155	.91	.13239	135.64	.007372
.42	.91958	83.096	.012034	.92	.13673	137.00	.007299
.43	.92392	.931	.011914	.93	.14107	138.38	.007227
.44	.92827	84.775	.011796	.94	.14541	139.77	.007155
4.45	1.93261	85.627	0.011679	4.95	2.14976	141.17	0.007083
.46	.93695	86.488	.011562	.96	.15410	142.59	.007013
.47	.94130	87.357	.011447	.97	.15844	144.03	.006943
.48	.94564	88.235	.011333	.98	.16279	145.47	.006874
.49	.94998	89.121	.011221	.99	.16713	146.94	.006806
4.50	1.95433	90.017	0.011109	5.00	2.17147	148.41	0.006738

Table 18 (*continued*).

EXPONENTIAL FUNCTION.

x	$\log_{10}(e^x)$	e^x	e^{-x}	x	$\log_{10}(e^x)$	e^x	e^{-x}
5.00	2.17147	148.41	0.006738	5.0	2.17147	148.41	0.006738
.01	.17582	149.90	.006671	.1	.21490	164.02	.006097
.02	.18016	151.41	.006605	.2	.25833	181.27	.005517
.03	.18450	152.93	.006539	.3	.30176	200.34	.004992
.04	.18884	154.47	.006474	.4	.34519	221.41	.004517
5.05	2.19319	156.02	0.006409	5.5	2.38862	244.69	0.004087
.06	.19753	157.59	.006346	.6	.43205	270.43	.003698
.07	.20187	159.17	.006282	.7	.47548	298.87	.003346
.08	.20622	160.77	.006220	.8	.51891	330.30	.003028
.09	.21056	162.39	.006158	.9	.56234	365.04	.002739
5.10	2.21490	164.02	0.006097	6.0	2.60577	403.43	0.002479
.11	.21924	165.67	.006036	.1	.64920	445.86	.002243
.12	.22359	167.34	.005976	.2	.69263	492.75	.002029
.13	.22793	169.02	.005917	.3	.73606	544.57	.001836
.14	.23227	170.72	.005858	.4	.77948	601.85	.001662
5.15	2.23662	172.43	0.005799	6.5	2.82291	665.14	0.001503
.16	.24096	174.16	.005742	.6	.86634	735.10	.001360
.17	.24530	175.91	.005685	.7	.90977	812.41	.001231
.18	.24965	177.68	.005628	.8	.95320	897.85	.001114
.19	.25399	179.47	.005572	.9	.99663	992.27	.001008
5.20	2.25833	181.27	0.005517	7.0	3.04006	1096.6	0.000912
.21	.26267	183.09	.005462	.1	.08349	1212.0	.000825
.22	.26702	184.93	.005407	.2	.12692	1339.4	.000747
.23	.27136	186.79	.005354	.3	.17035	1480.3	.000676
.24	.27570	188.67	.005300	.4	.21378	1636.0	.000611
5.25	2.28005	190.57	0.005248	7.5	3.25721	1808.0	0.000553
.26	.28439	192.48	.005195	.6	.30064	1998.2	.000500
.27	.28873	194.42	.005144	.7	.34407	2208.3	.000453
.28	.29307	196.37	.005092	.8	.38750	2440.6	.000410
.29	.29742	198.34	.005042	.9	.43093	2697.3	.000371
5.30	2.30176	200.34	0.004992	8.0	3.47436	2981.0	0.000335
.31	.30610	202.35	.004942	.1	.51779	3294.5	.000304
.32	.31045	204.38	.004893	.2	.56121	3641.0	.000275
.33	.31479	206.44	.004844	.3	.60464	4023.9	.000249
.34	.31913	208.51	.004796	.4	.64807	4447.1	.000225
5.35	2.32348	210.61	0.004748	8.5	3.69150	4914.8	0.000203
.36	.32782	212.72	.004701	.6	.73493	5431.7	.000184
.37	.33216	214.86	.004654	.7	.77836	6002.9	.000167
.38	.33650	217.02	.004608	.8	.82179	6634.2	.000151
.39	.34085	219.20	.004562	.9	.86522	7332.0	.000136
5.40	2.34519	221.41	0.004517	9.0	3.90865	8103.1	0.000123
.41	.34953	223.63	.004472	.1	.95208	8955.3	.000112
.42	.35388	225.88	.004427	.2	.99551	9897.1	.000101
.43	.35822	228.15	.004383	.3	4.03894	10938.	.000091
.44	.36256	230.44	.004339	.4	.08237	12088.	.000083
5.45	2.36690	232.76	0.004296	9.5	4.12580	13360.	0.000075
.46	.37125	235.10	.004254	.6	.16923	14765.	.000068
.47	.37559	237.46	.004211	.7	.21266	16318.	.000061
.48	.37993	239.85	.004169	.8	.25609	18034.	.000055
.49	.38428	242.26	.004128	.9	.29952	19930.	.000050
5.50	2.38862	244.69	0.004087	10.0	4.34294	22026.	0.000045

TABLE 19.

EXPONENTIAL FUNCTIONS.

Value of e^{x^2} and e^{-x^2} and their logarithms.

x	e^{x^2}	$\log e^{x^2}$	e^{-x^2}	$\log e^{-x^2}$
0.1	1.0101	0.00434	0.99005	$\bar{1}.99566$
2	1.0408	01737	96079	98263
3	1.0942	03909	91393	96091
4	1.1735	06949	85214	93051
5	1.2840	10857	77880	89143
0.6	1.4333	0.15635	0.69768	$\bar{1}.84365$
7	1.6323	21280	61263	78720
8	1.8965	27795	52729	72205
9	2.2479	35178	44486	64822
1.0	2.7183	43429	36788	56571
1.1	3.3535	0.52550	0.29820	$\bar{1}.47450$
2	4.2207	62538	23693	37462
3	5.4195	73396	18452	26604
4	7.0993	85122	14086	14878
5	9.4877	97716	10540	02284
1.6	1.2936×10	1.11179	0.77305×10^{-1}	$\bar{2}.88821$
7	1.7993 “	25511	55576 “	74489
8	2.5534 “	40711	39164 “	59289
9	3.6966 “	56780	27052 “	43220
2.0	5.4598 “	73718	18316 “	26282
2.1	8.2269 “	1.91524	0.12155 “	$\bar{2}.08476$
2	1.2647×10^2	2.10199	79071×10^{-2}	$\bar{3}.89801$
3	1.9834 “	29742	50418 “	70258
4	3.1735 “	50154	31511 “	49846
5	5.1801 “	71434	19305 “	28566
2.6	8.6264 “	2.93583	0.11592 “	$\bar{3}.06417$
7	1.4656×10^3	3.16601	68233×10^{-3}	$\bar{4}.83399$
8	2.5402 “	40487	39367 “	59513
9	4.4918 “	65242	22263 “	34758
3.0	8.1031 “	90865	12341 “	09135
3.1	1.4913×10^4	4.17357	0.67055×10^{-4}	$\bar{5}.82643$
2	2.8001 “	44718	35713 “	55282
3	5.3637 “	72947	18644 “	27053
4	1.0482×10^5	5.02044	95402×10^{-5}	$\bar{6}.97956$
5	2.0898 “	32011	47851 “	67989
3.6	4.2507 “	5.62846	0.23526 “	$\bar{6}.37154$
7	8.8205 “	94549	11337 “	05451
8	1.8673×10^6	6.27121	53553×10^{-6}	$\bar{7}.72879$
9	4.0329 “	60562	24796 “	39438
4.0	8.8861 “	94871	11254 “	05129
4.1	1.9975×10^7	7.30049	0.50062×10^{-7}	$\bar{8}.69951$
2	4.5809 “	66095	21830 “	33905
3	1.0718×10^8	8.03010	93303×10^{-8}	$\bar{9}.96990$
4	2.5582 “	40794	39089 “	59206
5	6.2296 “	79446	16052 “	20554
4.6	1.5476×10^9	9.18967	0.64614×10^{-9}	$\overline{10}.81033$
7	3.9225 “	59357	25494 “	40643
8	1.0142×10^{10}	10.00614	98595×10^{-10}	$\overline{11}.99386$
9	2.6755 “	42741	37376 “	57259
5.0	7.2005 “	85736	13888 “	14264

Table 20.

EXPONENTIAL FUNCTIONS.

Values of $e^{\frac{\pi}{4}x}$ and $e^{-\frac{\pi}{4}x}$ and their logarithms.

x	$e^{\frac{\pi}{4}x}$	$\log e^{\frac{\pi}{4}x}$	$e^{-\frac{\pi}{4}x}$	$\log e^{-\frac{\pi}{4}x}$
1	2.1933	0.34109	0.45594	$\bar{1}$.65891
2	4.8105	.68219	.20788	.31781
3	1.0551 × 10	1.02328	.94780 × 10^{-1}	$\bar{2}$.97672
4	2.3141	.36438	.43214	.63562
5	5.0754	.70547	.19703	.29453
6	1.1132 × 10^2	2.04656	0.89833 × 10^{-2}	$\bar{3}$.95344
7	2.4415	.38766	.40958	.61234
8	5.3549	.72875	.18674	.27125
9	1.1745 × 10^3	3.06985	.85144 × 10^{-3}	$\bar{4}$.93015
10	2.5760	.41094	.38820	.58906
11	5.6498	3.75203	0.17700	$\bar{4}$.24797
12	1.2392 × 10^4	4.09313	.80700 × 10^{-4}	$\bar{5}$.90687
13	2.7178	.43422	.36794	.56578
14	5.9610	.77532	.16776	.22468
15	1.3074 × 10^5	5.11641	.76487 × 10^{-5}	$\bar{6}$.88359
16	2.8675	5.45751	0.34873	$\bar{6}$.54249
17	6.2893	.79860	.15900	.20140
18	1.3794 × 10^6	6.13969	.72495 × 10^{-6}	$\bar{7}$.86031
19	3.0254	.48079	.33053	.51921
20	6.6356	.82188	.15070	.17812

Table 21.

EXPONENTIAL FUNCTIONS.

Values of $e^{\frac{\sqrt{\pi}}{4}x}$ and $e^{-\frac{\sqrt{\pi}}{4}x}$ and their logarithms.

x	$e^{\frac{\sqrt{\pi}}{4}x}$	$\log e^{\frac{\sqrt{\pi}}{4}x}$	$e^{-\frac{\sqrt{\pi}}{4}x}$	$\log e^{-\frac{\sqrt{\pi}}{4}x}$
1	1.5576	0.19244	0.64203	$\bar{1}$.80756
2	2.4260	.38488	.41221	.61512
3	3.7786	.57733	.26465	.42267
4	5.8853	.76977	.16992	.23023
5	9.1666	.96221	.10909	.03779
6	14.277	1.15465	0.070041	$\bar{2}$.84535
7	22.238	.34709	.044968	.65291
8	34.636	.53953	.028871	.46047
9	53.948	.73198	.018536	.26802
10	84.027	.92442	.011901	.07558
11	130.88	2.11686	0.0076408	$\bar{3}$.88314
12	203.85	.30930	.0049057	.69070
13	317.50	.50174	.0031496	.49826
14	494.52	.69418	.0020222	.30582
15	770.24	.88663	.0012983	.11337
16	1199.7	3.07907	0.00083355	$\bar{4}$.92093
17	1868.6	.27151	.00053517	.72849
18	2910.4	.46395	.00034360	.53605
19	4533.1	.65639	.00022060	.34361
20	7060.5	.84883	.00014163	.15117

TABLE 22. — Exponential Functions.

Value of ϵ^x and ϵ^{-x} and their logarithms.

x	ϵ^x	$\log \epsilon^x$	ϵ^{-x}	x	ϵ^x	$\log \epsilon^x$	ϵ^{-x}
1/64	1.0157	0.00679	0.98450	1/3	1.3956	0.14476	0.71653
1/32	.0317	.01357	.96923	1/2	.6487	.21715	.60653
1/16	.0645	.02714	.93941	3/4	2.1170	.32572	.47237
1/10	.1052	.04343	.90484	1	.7183	.43429	.36788
1/9	.1175	.04825	.89484	5/4	3.4903	.54287	.28650
1/8	1.1331	0.05429	0.88250	3/2	4.4817	0.65144	0.22313
1/7	.1536	.06204	.86688	7/4	5.7546	.76002	.17377
1/6	.1814	.07238	.84648	2	7.3891	.86859	.13534
1/5	.2214	.08686	.81873	9/4	9.4877	.97716	.10540
1/4	.2840	.10857	.77880	5/2	12.1825	1.08574	.08208

TABLE 23. — Least Squares.

Values of $P=\frac{2}{\sqrt{\pi}}\int_0^{hx} \epsilon^{-(hx)^2}\, d\,(hx)$.

This table gives the value of P, the probability of an observational error having a value positive or negative equal to or less than x when h is the measure of precision, $P = \frac{2}{\sqrt{\pi}}\int_0^{hx} \epsilon^{-(hx)^2} d(hx)$. For values of the inverse function see the table on Diffusion.

hx	0	1	2	3	4	5	6	7	8	9
0.0		.01128	.02256	.03384	.04511	.05637	.06762	.07886	.09008	.10128
.1	.11246	.12362	.13476	.14587	.15695	.16800	.17901	.18999	.20094	.21184
.2	.22270	.23352	.24430	.25502	.26570	.27633	.28690	.29742	.30788	.31828
.3	.32863	.33891	.34913	.35928	.36936	.37938	.38933	.39921	.40901	.41874
.4	.42839	.43797	.44747	.45689	.46623	.47548	.48466	.49375	.50275	.51167
0.5	.52050	.52924	.53790	.54646	.55494	.56332	.57162	.57982	.58792	.59594
.6	.60386	.61168	.61941	.62705	.63459	.64203	.64938	.65663	.66378	.67084
.7	.67780	.68467	.69143	.69810	.70468	.71116	.71754	.72382	.73001	.73610
.8	.74210	.74800	.75381	.75952	.76514	.77067	.77610	.78144	.78669	.79184
.9	.79691	.80188	.80677	.81156	.81627	.82089	.82542	.82987	.83423	.83851
1.0	.84270	.84681	.85084	.85478	.85865	.86244	.86614	.86977	.87333	.87680
.1	.88021	.88353	.88679	.88997	.89308	.89612	.89910	.90200	.90484	.90761
.2	.91031	.91296	.91553	.91805	.92051	.92290	.92524	.92751	.92973	.93190
.3	.93401	.93606	.93807	.94002	.94191	.94376	.94556	.94731	.94902	.95067
.4	.95229	.95385	.95538	.95686	.95830	.95970	.96105	.96237	.96365	.96490
1.5	.96611	.96728	.96841	.96952	.97059	.97162	.97263	.97360	.97455	.97546
.6	.97635	.97721	.97804	.97884	.97962	.98038	.98110	.98181	.98249	.98315
.7	.98379	.98441	.98500	.98558	.98613	.98667	.98719	.98769	.98817	.98864
.8	.98909	.98952	.98994	.99035	.99074	.99111	.99147	.99182	.99216	.99248
.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99999	.99999	1.00000						

Taken from a paper by Dr. James Burgess 'on the Definite Integral $\frac{2}{\sqrt{\pi}}\int_0^t \epsilon^{-t^2}\, dt$, with Extended Tables of Values.' Trans. Roy. Soc. of Edinburgh, vol. xxxix, 1900, p. 257.

Table 24.

LEAST SQUARES.

This table gives the values of the probability P, as defined in last table, corresponding to different values of x/r where r is the "probable error." The probable error r is equal to $0.47694/h$.

$\frac{x}{r}$	0	1	2	3	4	5	6	7	8	9
0.0	.00000	.00538	.01076	.01614	.02152	.02690	.03228	.03766	.04303	.04840
0.1	.05378	.05914	.06451	.06987	.07523	.08059	.08594	.09129	.09663	.10197
0.2	.10731	.11264	.11796	.12328	.12860	.13391	.13921	.14451	.14980	.15508
0.3	.16035	.16562	.17088	.17614	.18138	.18662	.19185	.19707	.20229	.20749
0.4	.21268	.21787	.22304	.22821	.23336	.23851	.24364	.24876	.25388	.25898
0.5	.26407	.26915	.27421	.27927	.28431	.28934	.29436	.29936	.30435	.30933
0.6	.31430	.31925	.32419	.32911	.33402	.33892	.34380	.34866	.35352	.35835
0.7	.36317	.36798	.37277	.37755	.38231	.38705	.39178	.39649	.40118	.40586
0.8	.41052	.41517	.41979	.42440	.42899	.43357	.43813	.44267	.44719	.45169
0.9	.45618	.46064	.46509	.46952	.47393	.47832	.48270	.48705	.49139	.49570
1.0	.50000	.50428	.50853	.51277	.51699	.52119	.52537	.52952	.53366	.53778
1.1	.54188	.54595	.55001	.55404	.55806	.56205	.56602	.56998	.57391	.57782
1.2	.58171	.58558	.58942	.59325	.59705	.60083	.60460	.60833	.61205	.61575
1.3	.61942	.62308	.62671	.63032	.63391	.63747	.64102	.64454	.64804	.65152
1.4	.65498	.65841	.66182	.66521	.66858	.67193	.67526	.67856	.68184	.68510
1.5	.68833	.69155	.69474	.69791	.70106	.70419	.70729	.71038	.71344	.71648
1.6	.71949	.72249	.72546	.72841	.73134	.73425	.73714	.74000	.74285	.74567
1.7	.74847	.75124	.75400	.75674	.75945	.76214	.76481	.76746	.77009	.77270
1.8	.77528	.77785	.78039	.78291	.78542	.78790	.79036	.79280	.79522	.79761
1.9	.79999	.80235	.80469	.80700	.80930	.81158	.81383	.81607	.81828	.82048
2.0	.82266	.82481	.82695	.82907	.83117	.83324	.83530	.83734	.83936	.84137
2.1	.84335	.84531	.84726	.84919	.85109	.85298	.85486	.85671	.85854	.86036
2.2	.86216	.86394	.86570	.86745	.86917	.87088	.87258	.87425	.87591	.87755
2.3	.87918	.88078	.88237	.88395	.88550	.88705	.88857	.89008	.89157	.89304
2.4	.89450	.89595	.89738	.89879	.90019	.90157	.90293	.90428	.90562	.90694
2.5	.90825	.90954	.91082	.91208	.91332	.91456	.91578	.91698	.91817	.91935
2.6	.92051	.92166	.92280	.92392	.92503	.92613	.92721	.92828	.92934	.93038
2.7	.93141	.93243	.93344	.93443	.93541	.93638	.93734	.93828	.93922	.94014
2.8	.94105	.94195	.94284	.94371	.94458	.94543	.94627	.94711	.94793	.94874
2.9	.94954	.95033	.95111	.95187	.95263	.95338	.95412	.95484	.95557	.95628
	0	1	2	3	4	5	6	7	8	9
3	.95698	.96346	.96910	.97397	.97817	.98176	.98482	.98743	.98962	.99147
4	.99302	.99431	.99539	99627	.99700	.99760	.99808	.99848	.99879	.99905
5	.99926	.99943	.99956	.99966	.99974	.99980	.99985	.99988	.99991	.99993

Table 25.

LEAST SQUARES.

Values of the factor $0.6745\sqrt{\frac{1}{n-1}}$.

This factor occurs in the equation $r_s = 0.6745\sqrt{\frac{\Sigma v^2}{n-1}}$ for the probable error of a single observation, and other similar equations.

n	=	1	2	3	4	5	6	7	8	9
00			0.6745	0.4769	0.3894	0.3372	0.3016	0.2754	0.2549	0.2385
10	0.2248	0.2133	.2034	.1947	.1871	.1803	.1742	.1686	.1636	.1590
20	.1547	.1508	.1472	.1438	.1406	.1377	.1349	.1323	.1298	.1275
30	.1252	.1231	.1211	.1192	.1174	.1157	.1140	.1124	.1109	.1094
40	.1080	.1066	.1053	.1041	.1029	.1017	.1005	.0994	.0984	.0974
50	0.0964	0.0954	0.0944	0.0935	0.0926	0.0918	0.0909	0.0901	0.0893	0.0886
60	.0878	.0871	.0864	.0857	.0850	.0843	.0837	.0830	.0824	.0818
70	.0812	.0806	.0800	.0795	.0789	.0784	.0779	.0774	.0769	.0764
80	.0759	.0754	.0749	.0745	.0740	.0736	.0732	.0727	.0723	.0719
90	.0715	.0711	.0707	.0703	.0699	.0696	.0692	.0688	.0685	.0681

Table 26.—LEAST SQUARES.

Values of the factor $0.6745\sqrt{\frac{1}{n(n-1)}}$.

This factor occurs in the equation $r_0=0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}$ for the probable error of the arithmetic mean.

n =		1	2	3	4	5	6	7	8	9
00			0.4769	0.2754	0.1947	0.1508	0.1231	0.1041	0.0901	0.0795
10	0.0711	0.0643	.0587	.0540	.0500	.0465	.0435	.0409	.0386	.0365
20	.0346	.0329	.0314	.0300	.0287	.0275	.0265	.0255	.0245	.0237
30	.0229	.0221	.0214	.0208	.0201	.0196	.0190	.0185	.0180	.0175
40	.0171	.0167	.0163	.0159	.0155	.0152	.0148	.0145	.0142	.0139
50	0.0136	0.0134	0.0131	0.0128	0.0126	0.0124	0.0122	0.0119	0.0117	0.0115
60	.0113	.0111	.0110	.0108	.0106	.0105	.0103	.0101	.0100	.0098
70	.0097	.0096	.0094	.0093	.0092	.0091	.0089	.0088	.0087	.0086
80	.0085	.0084	.0083	.0082	.0081	.0080	.0079	.0078	.0077	.0076
90	.0075	.0075	.0074	.0073	.0072	.0071	.0071	.0070	.0069	.0068

Table 27.—LEAST SQUARES.

Values of the factor $0.8453\sqrt{\frac{1}{n(n-1)}}$.

This factor occurs in the approximate equation $r=0.8453\frac{\Sigma v}{\sqrt{n(n-1)}}$ for the probable error of a single observation.

n =		1	2	3	4	5	6	7	8	9
00			0.5978	0.3451	0.2440	0.1890	0.1543	0.1304	0.1130	0.0996
10	0.0891	0.0806	.0736	.0677	.0627	.0583	.0546	.0513	.0483	.0457
20	.0434	.0412	.0393	.0376	.0360	.0345	.0332	.0319	.0307	.0297
30	.0287	.0277	.0268	.0260	.0252	.0245	.0238	.0232	.0225	.0220
40	.0214	.0209	.0204	.0199	.0194	.0190	.0186	.0182	.0178	.0174
50	0.0171	0.0167	0.0164	0.0161	0.0158	0.0155	0.0152	0.0150	0.0147	0.0145
60	.0142	.0140	.0137	.0135	.0133	.0131	.0129	.0127	.0125	.0123
70	.0122	.0120	.0118	.0117	.0115	.0113	.0112	.0111	.0109	.0108
80	.0106	.0105	.0104	.0102	.0101	.0100	.0099	.0098	.0097	.0096
90	.0094	.0093	.0092	.0091	.0090	.0089	.0089	.0088	.0087	.0086

Table 28.—LEAST SQUARES.

Values of $0.8453\frac{1}{n\sqrt{n-1}}$.

This factor occurs in the approximate equation $r_0=0.8453\frac{1}{n\sqrt{n-1}}$ for the probable error of the arithmetical mean.

n =		1	2	3	4	5	6	7	8	9
00			0.4227	0.1993	0.1220	0.0845	0.0630	0.0493	0.0399	0.0332
10	0.0282	0.0243	.0212	.0188	.0167	.0151	.0136	.0124	.0114	.0105
20	.0097	.0090	.0084	.0078	.0073	.0069	.0065	.0061	.0058	.0055
30	.0052	.0050	.0047	.0045	.0043	.0041	.0040	.0038	.0037	.0035
40	.0034	.0033	.0031	.0030	.0029	.0028	.0027	.0027	.0026	.0025
50	0.0024	0.0023	0.0023	0.0022	0.0022	0.0021	0.0020	0.0020	0.0019	0.0019
60	.0018	.0018	.0017	.0017	.0017	.0016	.0016	.0016	.0015	.0015
70	.0015	.0014	.0014	.0014	.0013	.0013	.0013	.0013	.0012	.0012
80	.0012	.0012	.0011	.0011	.0011	.0011	.0011	.0010	.0010	.0010
90	.0010	.0010	.0010	.0009	.0009	.0009	.0009	.0009	.0009	.0009

LEAST SQUARES.

Observation equations:

$$a_1z_1 + b_1z_2 + \ldots l_1z_q = M_1, \text{ weight } p_1$$
$$a_2z_1 + b_2z_2 + \ldots l_2z_q = M_2. \text{ weight } p_2$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$a_nz_1 + b_nz_2 + \ldots l_nz_q = M_n, \text{ weight } p_n.$$

Auxiliary equations:

$$[paa] = p_1a_1^2 + p_2a_2^2 + \ldots p_na_n^2.$$
$$[pab] = p_1a_1b_1 + p_2a_2b_2 + \ldots p_na_nb_n.$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$[paM] = p_1a_1M_1 + p_2a_2M_2 + \ldots p_na_nM_n.$$

Normal equations:

$$[paa]z_1 + [pab]z_2 + \ldots [pal]z_q = [paM]$$
$$[pab]z_1 + [pbb]z_2 + \ldots [pbl]z_q = [pbM]$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$[pla]z_1 + [plb]z_2 + \ldots [pll]z_q = [plM].$$

Solution of normal equations in the form,

$$z_1 = A_1[paM] + B_1[pbM] + \ldots L_1[plM]$$
$$z_2 = A_2[paM] + B_2[pbM] + \ldots L_2[plM]$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$z_q = A_n[paM] + B_n[pbM] + \ldots L_n[plM],$$

gives:

$$\text{weight of } z_1 = p_{z_1} = (A_1)^{-1}; \text{ probable error of } z_1 = \frac{r}{\sqrt{p_{z_1}}}$$
$$\text{weight of } z_2 = p_{z_2} = (B_2)^{-1}; \text{ probable error of } z_2 = \frac{r}{\sqrt{p_{z_2}}}$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$\text{weight of } z_q = p_{z_q} = (L_n)^{-1}; \text{ probable error of } z_q = \frac{r}{\sqrt{p_{z_q}}}$$

wherein

$$r = \text{probable error of observation of weight unity}$$
$$= 0.6745\sqrt{\frac{\Sigma pv^2}{n-q}}. \text{ (q unknowns.)}$$

Arithmetical mean, n observations:

$$r = 0.6745\sqrt{\frac{\Sigma v^2}{n-1}} = \frac{0.8453\,\Sigma v}{\sqrt{n(n-1)}}.$$ (approx.) = probable error of observation of weight unity.

$$r_0 = 0.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}} = \frac{0.8453\,\Sigma v}{n\sqrt{n-1}}.$$ (approx.) = probable error of mean.

Weighted mean, n observations:

$$r = 0.6745\sqrt{\frac{\Sigma p v^2}{n-1}}; \quad r_0 = \frac{r}{\sqrt{\Sigma p}} = 0.6745\sqrt{\frac{\Sigma p v^2}{(n-1)\Sigma p}}$$

Probable error (R) of a function (Z) of several observed quantities $z_1, z_2, \ldots$ whose probable errors are respectively, $r_1, r_2, \ldots$.

$$Z = f(z_1, z_2, \ldots)$$
$$R^2 = \left(\frac{\partial Z}{\partial z_1}\right)^2 r_1^2 + \left(\frac{\partial Z}{\partial z_2}\right)^2 r_2^2 + \ldots$$

Examples:

$$Z = z_1 \pm z_2 + \ldots \qquad R^2 = r_1^2 + r_2^2 + \ldots$$
$$Z = Az_1 \pm Az_2 \pm \ldots \qquad R^2 = A^2 r_1^2 + B^2 r_2^2 + \ldots$$
$$Z = z_1 z_2. \qquad R^2 = z_1 r_2^2 + z_2 r_1^2.$$

Table 30.

DIFFUSION.

Inverse * values of $v/c = 1 - \frac{2}{\sqrt{\pi}} \int_0^q e^{-q^2} dq.$

$\log x = \log (2q) + \log \sqrt{kt}.$ t expressed in seconds.
$= \log \delta + \log \sqrt{kt}.$ t expressed in days.
$= \log \gamma + \log \sqrt{kt}.$ " " years.
k = coefficient of diffusion.†
c = initial concentration.
v = concentration at distance x, time t.

v/c	log 2q	2q	log δ	δ	log γ	γ
0.00	+∞	+∞	+∞	+∞	∞	∞
.01	0.56143	3.6428	3.02970	1070.78	4.31098	20463.
.02	.51719	3.2900	2.98545	967.04	.26674	18481.
.03	.48699	3.0690	.95525	902.90	.23654	17240.
.04	.46306	2.9044	.93132	853.73	.21261	16316.
0.05	0.44276	2.7718	2.91102	814.74	4.19231	15571.
.06	.42486	2.6598	.89311	781.83	.17440	14942.
.07	.40865	2.5624	.87691	753.20	.15820	14395.
.08	.39372	2.4758	.86198	727.75	.14327	13908.
.09	.37979	2.3977	.84804	704.76	.12933	13469.
0.10	0.36664	2.3262	2.83490	683.75	4.11619	13067.
.11	.35414	2.2602	.82240	664.36	.10369	12697.
.12	.34218	2.1988	.81044	646.31	.09173	12352.
.13	.33067	2.1413	.79893	629.40	.08022	12029.
.14	.31954	2.0871	.78780	613.47	.06909	11724.
0.15	0.30874	2.0358	2.77699	598.40	4.05828	11436.
.16	.29821	1.9871	.76647	584.08	.04776	11162.
.17	.28793	1.9406	.75619	570.41	.03748	10901.
.18	.27786	1.8961	.74612	557.34	.02741	10652.
.19	.26798	1.8534	.73624	544.80	.01753	10412.
0.20	0.25825	1.8124	2.72651	532.73	4.00780	10181.
.21	.24866	1.7728	.71692	521.10	3.99821	9958.9
.22	.23919	1.7346	.70745	509.86	.98874	9744.1
.23	.22983	1.6976	.69808	498.98	.97937	9536.2
.24	.22055	1.6617	.68880	488.43	.97010	9334.6
0.25	0.21134	1.6268	2.67960	478.19	3.96089	9138.9
.26	.20220	1.5930	.67046	468.23	.95175	8948.5
.27	.19312	1.5600	.66137	458.53	.94266	8763.2
.28	.18407	1.5278	.65232	449.08	.93361	8582.5
.29	.17505	1.4964	.64331	439.85	.92460	8406.2
0.30	0.16606	1.4657	2.63431	430.84	3.91560	8233.9
.31	.15708	1.4357	.62533	422.02	.90662	8065.4
.32	.14810	1.4064	.61636	413.39	.89765	7900.4
.33	.13912	1.3776	.60738	404.93	.88867	7738.8
.34	.13014	1.3494	.59840	396.64	.87969	7580.3
0.35	0.12114	1.3217	2.58939	388.50	3.87068	7424.8
.36	.11211	1.2945	.58037	380.51	.86166	7272.0
.37	.10305	1.2678	.57131	372.66	.85260	7122.0
.38	.09396	1.2415	.56222	364.93	.84351	6974.4
.39	.08482	1.2157	.55308	357.34	.83437	6829.2
0.40	0.07563	1.1902	2.54389	349.86	3.82518	6686.2
.41	.06639	1.1652	.53464	342.49	.81593	6545.4
.42	.05708	1.1405	.52533	335.22	.80662	6406.6
.43	.04770	1.1161	.51595	328.06	.79724	6269.7
.44	.03824	1.0920	.50650	320.99	.78779	6134.6
0.45	0.02870	1.0683	2.49696	314.02	3.77825	6001.3
.46	.01907	1.0449	.48733	307.13	.76862	5869.7
.47	.00934	1.0217	.47760	300.33	.75889	5739.7
.48	9.99951	0.99886	.46776	293.60	.74905	5611.2
.49	.98956	0.97624	.45782	286.96	.73911	5484.1
0.50	9.97949	0.95387	2.44775	280.38	3.72904	5358.4

* Kelvin, Mathematical and Physical Papers, vol. III. p. 428; Becker, Am. Jour. of Sci. vol. III. 1897, p. 280.

† For direct values see table 23.

DIFFUSION.

v/c	log 2q	2q	log δ	δ	log γ	γ
0.50	9.97949	0.95387	2.44775	280.38	3.72904	5358.4
.51	.96929	.93174	.43755	273.87	.71884	5234.1
.52	.95896	.90983	.42722	267.43	.70851	5111.0
.53	.94848	.88813	.41674	261.06	.69803	4989.1
.54	.93784	.86665	.40610	254.74	.68739	4868.4
0.55	9.92704	0.84536	2.39530	248.48	3.67659	4748.9
.56	.91607	.82426	.38432	242.28	.66561	4630.3
.57	.90490	.80335	.37316	236.13	.65445	4512.8
.58	.89354	.78260	.36180	230.04	.64309	4396.3
.59	.88197	.76203	.35023	223.99	.63152	4280.7
0.60	9.87018	0.74161	2.33843	217.99	3.61973	4166.1
.61	.85815	.72135	.32640	212.03	.60770	4052.2
.62	.84587	.70124	.31412	206.12	.59541	3939.2
.63	.83332	.68126	.30157	200.25	.58286	3827.0
.64	.82048	.66143	.28874	194.42	.57003	3715.6
0.65	9.80734	0.64172	2.27560	188.63	3.55689	3604.9
.66	.79388	.62213	.26214	182.87	.54343	3494.9
.67	.78008	.60266	.24833	177.15	.52962	3385.4
.68	.76590	.58331	.23416	171.46	.51545	3276.8
.69	.75133	.56407	.21959	165.80	.50088	3168.7
0.70	9.73634	0.54493	2.20459	160.17	3.48588	3061.1
.71	.72089	.52588	.18915	154.58	.47044	2954.2
.72	.70495	.50694	.17321	149.01	.45450	2847.7
.73	.68849	.48808	.15675	143.47	.43804	2741.8
.74	.67146	.46931	.13972	137.95	.42101	2636.4
0.75	9.65381	0.45062	2.12207	132.46	3.40336	2531.4
.76	.63550	.43202	.10376	126.99	.38505	2426.9
.77	.61646	.41348	.08471	121.54	.36600	2322.7
.78	.59662	.39502	.06487	116.11	.34616	2219.0
.79	.57590	.37662	.04416	110.70	.32545	2115.7
0.80	9.55423	0.35829	2.02249	105.31	3.30378	2012.7
.81	.53150	.34001	1.99975	99.943	.28104	1910.0
.82	.50758	.32180	.97584	94.589	.25713	1807.7
.83	.48235	.30363	.95061	89.250	.23190	1705.7
.84	.45564	.28552	.92389	83.926	.20518	1603.9
0.85	9.42725	0.26745	1.89551	78.615	3.17680	1502.4
.86	.39695	.24943	.86521	73.317	.14650	1401.2
.87	.36445	.23145	.83271	68.032	.11400	1300.2
.88	.32940	.21350	.79766	62.757	.07895	1199.4
.89	.29135	.19559	.75961	57.492	3.04090	1098.7
0.90	9.24972	0.17771	1.71797	52.236	2.99926	998.31
.91	.20374	.15986	.67200	46.989	.95329	898.03
.92	.15239	.14203	.62065	41.750	.90194	797.89
.93	.09423	.12423	.56249	36.516	.84378	697.88
.94	9.02714	.10645	.49539	31.289	.77668	597.98
0.95	8.94783	0.08868	1.41609	26.067	2.69738	498.17
.96	.85082	.07093	.31907	20.848	.60036	398.44
.97	.72580	.05319	.19406	15.633	.47535	298.78
.98	.54965	.03545	.01791	10.421	.29920	199.16
.99	.24859	.01773	9.71684	5.21007	1.99813	99.571
1.00	—∞	0.00000	—∞	0.00000	—∞	0.000

TABLE 31.

GAMMA FUNCTION.*

$$\text{Value of } \log \int_0^\infty e^{-x} x^{n-1} dx + 10.$$

Values of the logarithms + 10 of the "Second Eulerian Integral" (Gamma function) $\int_0^\infty e^{-x}x^{n-1}dx$ or $\log \Gamma(n) + 10$ for values of n between 1 and 2. When n has values not lying between 1 and 2 the value of the function can be readily calculated from the equation $\Gamma(n+1) = n\Gamma(n) = n(n-1) \ldots (n-r)\Gamma(n-r)$.

n	0	1	2	3	4	5	6	7	8	9
1.00	9.99——	97497	95001	92512	90030	87555	85087	82627	80173	77727
1.01	75287	72855	70430	68011	65600	63196	60798	58408	56025	53648
1.02	51279	48916	46561	44212	41870	39535	37207	34886	32572	30265
1.03	27964	25671	23384	21104	18831	16564	14305	12052	09806	07567
1.04	05334	03108	00889	98677	96471	94273	92080	89895	87716	85544
1.05	9.9883379	81220	79068	76922	74783	72651	70525	68406	66294	64188
1.06	62089	59996	57910	55830	53757	51690	49630	47577	45530	43489
1.07	41455	39428	37407	35392	33384	31382	29387	27398	25415	23439
1.08	21469	19506	17549	15599	13655	11717	09785	07860	05941	04029
1.09	02123	00223	98329	96442	94561	92686	90818	88956	87100	85250
1.10	9.9783407	81570	79738	77914	76095	74283	72476	70676	68882	67095
1.11	65313	63538	61768	60005	58248	56497	54753	53014	51281	49555
1.12	47834	46120	44411	42709	41013	39323	37638	35960	34288	32622
1.13	30962	29308	27659	26017	24381	22751	21126	19508	17896	16289
1.14	14689	13094	11505	09922	08345	06774	05209	03650	02096	00549
1.15	9.9699007	97471	95941	94417	92898	91386	89879	88378	86883	85393
1.16	83910	82432	80960	79493	78033	76578	75129	73686	72248	70816
1.17	69390	67969	66554	65145	63742	62344	60952	59566	58185	56810
1.18	55440	54076	52718	51366	50019	48677	47341	46011	44687	43368
1.19	42054	40746	39444	38147	36856	35570	34290	33016	31747	30483
1.20	9.9629225	27973	26725	25484	24248	23017	21792	20573	19358	18150
1.21	16946	15748	14556	13369	12188	11011	09841	08675	07515	06361
1.22	05212	04068	02930	01796	00669	99546	98430	97318	96212	95111
1.23	594015	92925	91840	90760	89685	88616	87553	86494	85441	84393
1.24	83350	82313	81280	80253	79232	78215	77204	76198	75197	74201
1.25	9.9573211	72226	71246	70271	69301	68337	67377	66423	65474	64530
1.26	63592	62658	61730	60806	59888	58975	58067	57165	56267	55374
1.27	54487	53604	52727	51855	50988	50126	49268	48416	47570	46728
1.28	45891	45059	44232	43410	42593	41782	40975	40173	39376	38585
1.29	37798	37016	36239	35467	34700	33938	33181	32429	31682	30940
1.30	9.9530203	29470	28743	28021	27303	26590	25883	25180	24482	23789
1.31	23100	22417	21739	21065	20396	19732	19073	18419	17770	17125
1.32	16485	15850	15220	14595	13975	13359	12748	12142	11541	10944
1.33	10353	09766	09184	08606	08034	07466	06903	06344	05791	05242
1.34	04698	04158	03624	03094	02568	02048	01532	01021	00514	00012
1.35	9.9499515	99023	98535	98052	97573	97100	96630	96166	95706	95251
1.36	94800	94355	93913	93477	93044	92617	92194	91776	91362	90953
1.37	90549	90149	89754	89363	88977	88595	88218	87846	87478	87115
1.38	86756	86402	86052	85707	85366	85030	84698	84371	84049	83731
1.39	83417	83108	82803	82503	82208	81916	81630	81348	81070	80797
1.40	9.9480528	80263	80003	79748	79497	79250	79008	78770	78537	78308
1.41	78084	77864	77648	77437	77230	77027	76829	76636	76446	76261
1.42	76081	75905	75733	75565	75402	75243	75089	74939	74793	74652
1.43	74515	74382	74254	74130	74010	73894	73783	73676	73574	73476
1.44	73382	73292	73207	73125	73049	72976	72908	72844	72784	72728

* Legendre's "Exercises de Calcul Intégral," tome ii.

GAMMA FUNCTION.

n	0	1	2	3	4	5	6	7	8	9
1.45	9.9472677	72630	72587	72549	72514	72484	72459	72437	72419	72406
1.46	72397	72393	72392	72396	72404	72416	72432	72452	72477	72506
1.47	72539	72576	72617	72662	72712	72766	72824	72886	72952	73022
1.48	73097	73175	73258	73345	73436	73531	73630	73734	73841	73953
1.49	74068	74188	74312	74440	74572	74708	74848	74992	75141	75293
1.50	9.9475449	75610	75774	75943	76116	76292	76473	76658	76847	77040
1.51	77237	77437	77642	77851	78064	78281	78502	78727	78956	79189
1.52	79426	79667	79912	80161	80414	80671	80932	81196	81465	81738
1.53	82015	82295	82580	82868	83161	83457	83758	84062	84370	84682
1.54	84998	85318	85642	85970	86302	86638	86977	87321	87668	88019
1.55	9.9488374	88733	89096	89463	89834	90208	90587	90969	91355	91745
1.56	92139	92537	92938	93344	93753	94166	94583	95004	95429	95857
1.57	96289	96725	97165	97609	98056	98508	98963	99422	99885	00351
1.58	500822	01296	01774	02255	02741	03230	03723	04220	04720	05225
1.59	05733	06245	06760	07280	07803	08330	08860	09395	09933	10475
1.60	9.9511020	11569	12122	12679	13240	13804	14372	14943	15519	16098
1.61	16680	17267	17857	18451	19048	19649	20254	20862	21475	22091
1.62	22710	23333	23960	24591	25225	25863	26504	27149	27798	28451
1.63	29107	29766	30430	31097	31767	32442	33120	33801	34486	35175
1.64	35867	36563	37263	37966	38673	39383	40097	40815	41536	42260
1.65	9.9542989	43721	44456	45195	45938	46684	47434	48187	48944	49704
1.66	50468	51236	52007	52782	53560	54342	55127	55916	56708	57504
1.67	58303	59106	59913	60723	61536	62353	63174	63998	64825	65656
1.68	66491	67329	68170	69015	69864	70716	71571	72430	73293	74159
1.69	75028	75901	76777	77657	78540	79427	80317	81211	82108	83008
1.70	9.9583912	84820	85731	86645	87563	88484	89409	90337	91268	92203
1.71	93141	94083	95028	95977	96929	97884	98843	99805	00771	01740
1.72	602712	03688	04667	05650	06636	07625	08618	09614	10613	11616
1.73	12622	13632	14645	15661	16681	17704	18730	19760	20793	21830
1.74	22869	23912	24959	26009	27062	28118	29178	30241	31308	32377
1.75	9.9633451	34527	35607	36690	37776	38866	39959	41055	42155	43258
1.76	44364	45473	46586	47702	48821	49944	51070	52199	53331	54467
1.77	55606	56749	57894	59043	60195	61350	62509	63671	64836	66004
1.78	67176	68351	69529	70710	71895	73082	74274	75468	76665	77866
1.79	79070	80277	81488	82701	83918	85138	86361	87588	88818	90051
1.80	9.9691287	92526	93768	95014	96263	97515	98770	00029	01291	02555
1.81	703823	05095	06369	07646	08927	10211	11498	12788	14082	15378
1.82	16678	17981	19287	20596	21908	23224	24542	25864	27189	28517
1.83	29848	31182	32520	33860	35204	36551	37900	39254	40610	41969
1.84	43331	44697	46065	47437	48812	50190	51571	52955	54342	55733
1.85	9.9757126	58522	59922	61325	62730	64139	65551	66966	68384	69805
1.86	71230	72657	74087	75521	76957	78397	79839	81285	82734	84186
1.87	85640	87098	88559	90023	91490	92960	94433	95909	97389	98871
1.88	800356	01844	03335	04830	06327	07827	09331	10837	12346	13859
1.89	15374	16893	18414	19939	21466	22996	24530	26066	27606	29148
1.90	9.9830693	32242	33793	35348	36905	38465	40028	41595	43164	44736
1.91	46311	47890	49471	51055	52642	54232	55825	57421	59020	60621
1.92	62226	63834	65445	67058	68675	70294	71917	73542	75170	76802
1.93	78436	80073	81713	83356	85002	86651	88302	89957	91614	93275
1.94	94938	96605	98274	99946	01621	03299	04980	06663	08350	10039
1.95	9.9911732	13427	15125	16826	18530	20237	21947	23659	25375	27093
1.96	28815	30539	32266	33995	35728	37464	39202	40943	42688	44435
1.97	46185	47937	49693	51451	53213	54977	56744	58513	60286	62062
1.98	63840	65621	67405	69192	70982	72774	74570	76368	78169	79972
1.99	81779	83588	85401	87216	89034	90854	92678	94504	96333	98165

Table 32.

ZONAL SPHERICAL HARMONICS.*

Degrees	P_1	P_2	P_3	P_4	P_5	P_6	P_7
0	+ 1.0000	+ 1.0000	+ 1.0000	+ 1.0000	+ 1.0000	+ 1.0000	+ 1.0000
1	.9998	.9995	.9991	.9985	.9977	.9968	.9957
2	.9994	.9982	.9963	.9939	.9909	.9872	.9830
3	.9986	.9959	.9918	.9863	.9795	.9714	.9620
4	.9976	.9927	.9854	.9758	.9638	.9495	.9329
5	+ 0.9962	+ 0.9886	+ 0.9773	+ 0.9623	+ 0.9437	+ 0.9216	+ 0.8962
6	.9945	.9836	.9674	.9459	.9194	.8881	.8522
7	.9925	.9777	.9557	.9267	.8911	.8492	.8016
8	.9903	.9709	.9423	.9048	.8589	.8054	.7449
9	.9877	.9633	.9273	.8803	.8232	.7570	.6830
10	+ 0.9848	+ 0.9548	+ 0.9106	+ 0.8532	+ 0.7840	+ 0.7045	+ 0.6164
11	.9816	.9454	.8923	.8238	.7417	.6483	.5462
12	.9781	.9352	.8724	.7920	.6966	.5891	.4731
13	.9744	.9241	.8511	.7582	.6489	.5273	.3980
14	.9703	.9122	.8283	.7224	.5990	.4635	.3218
15	+ 0.9659	+ 0.8995	+ 0.8042	+ 0.6847	+ 0.5471	+ 0.3983	+ 0.2455
16	.9613	.8860	.7787	.6454	.4937	.3323	+ .1700
17	.9563	.8718	.7519	.6046	.4391	.2661	+ .0961
18	.9511	.8568	.7240	.5624	.3836	.2002	+ .0248
19	.9455	.8410	.6950	.5192	.3276	.1353	− .0433
20	+ 0.9397	+ 0.8245	+ 0.6649	+ 0.4750	+ 0.2715	+ 0.0719	− 0.1072
21	.9336	.8074	.6338	.4300	.2156	+ .0106	.1664
22	.9272	.7895	.6019	.3845	.1602	− .0481	.2202
23	.9205	.7710	.5692	.3386	.1057	− .1038	.2680
24	.9135	.7518	.5357	.2926	.0525	− .1558	.3094
25	+ 0.9063	+ 0.7321	+ 0.5016	+ 0.2465	+ 0.0009	− 0.2040	− 0.3441
26	.8988	.7117	.4670	.2007	− .0489	.2478	.3717
27	.8910	.6908	.4319	.1553	− .0964	.2869	.3922
28	.8829	.6694	.3964	.1105	− .1415	.3212	.4053
29	.8746	.6474	.3607	.0665	− .1839	.3502	.4113
30	+ 0.8660	+ 0.6250	+ 0.3248	+ 0.0234	− 0.2233	− 0.3740	− 0.4102
31	.8572	.6021	.2887	− .0185	.2595	.3924	.4022
32	.8480	.5788	.2527	− .0591	.2923	.4053	.3877
33	.8387	.5551	.2167	− .0982	.3216	.4127	.3671
34	.8290	.5310	.1809	− .1357	.3473	.4147	.3409
35	+ 0.8192	+ 0.5065	+ 0.1454	− 0.1714	− 0.3691	− 0.4114	− 0.3096
36	.8090	.4818	.1102	.2052	.3871	.4031	.2738
37	.7986	.4567	.0755	.2370	.4011	.3898	.2343
38	.7880	.4314	.0413	.2666	.4112	.3719	.1918
39	.7771	.4059	.0077	.2940	.4174	.3497	.1470
40	+ 0.7660	+ 0.3802	− 0.0252	− 0.3190	− 0.4197	− 0.3236	− 0.1006
41	.7547	.3544	.0574	.3416	.4181	.2939	− .0535
42	.7431	.3284	.0887	.3616	.4128	.2610	− .0064
43	.7314	.3023	.1191	.3791	.4038	.2255	+ .0398
44	.7193	.2762	.1485	.3940	.3914	.1878	+ .0846
45	+ 0.7071	+ 0.2500	− 0.1768	− 0.4063	− 0.3757	− 0.1484	+ 0.1271
46	.6947	.2238	.2040	.4158	.3568	− .1078	.1667
47	.6820	.1977	.2300	.4227	.3350	− .0665	.2028
48	.6691	.1716	.2547	.4270	.3105	− .0251	.2350
49	.6561	.1456	.2781	.4286	.2836	+ .0161	.2626
50	+ 0.6428	+ 0.1198	− 0.3002	− 0.4275	− 0.2545	+ 0.0564	+ 0.2854

* Calculated by Mr. C. E. Van Orstrand for this publication.

Table 32 (*continued*).

ZONAL SPHERICAL HARMONICS.

Degrees	P_1	P_2	P_3	P_4	P_5	P_6	P_7
50	+ 0.6428	+ 0.1198	− 0.3002	− 0.4275	− 0.2545	+ 0.0564	+ 0.2854
51	.6293	.0941	.3209	.4239	.2235	.0954	.3031
52	.6157	.0686	.3401	.4178	.1910	.1326	.3154
53	.6018	.0433	.3578	.4093	.1571	.1677	.3221
54	.5878	.0182	.3740	.3984	.1223	.2002	.3234
55	+ 0.5736	− 0.0065	− 0.3886	− 0.3852	− 0.0868	+ 0.2297	+ 0.3191
56	.5592	.0310	.4016	.3698	− .0509	.2560	.3095
57	.5446	.0551	.4131	.3524	− .0150	.2787	.2947
58	.5299	.0788	.4229	.3331	+ .0206	.2976	.2752
59	.5150	.1021	.4310	.3119	+ .0557	.3125	.2512
60	+ 0.5000	− 0.1250	− 0.4375	− 0.2891	+ 0.0898	+ 0.3232	+ 0.2231
61	.4848	.1474	.4423	.2647	.1229	.3298	.1916
62	.4695	.1694	.4455	.2390	.1545	.3321	.1572
63	.4540	.1908	.4471	.2121	.1844	.3302	.1203
64	.4384	.2117	.4470	.1841	.2123	.3240	.0818
65	+ 0.4226	− 0.2321	− 0.4452	− 0.1552	+ 0.2381	+ 0.3138	+ 0.0422
66	.4067	.2518	.4419	.1256	.2615	.2997	+ .0022
67	.3907	.2710	.4370	.0955	.2824	.2819	− .0375
68	.3746	.2895	.4305	.0651	.3005	.2606	− .0763
69	.3584	.3074	.4225	.0344	.3158	.2362	− .1135
70	+ 0.3420	− 0.3245	− 0.4130	− 0.0038	+ 0.3281	+ 0.2089	− 0.1485
71	.3256	.3410	.4021	+ .0267	.3373	.1791	.1808
72	.3090	.3568	.3898	.0568	.3434	.1472	.2099
73	.2924	.3718	.3761	.0864	.3463	.1136	.2352
74	.2756	.3860	.3611	.1153	.3461	.0788	.2563
75	+ 0.2588	− 0.3995	− 0.3449	+ 0.1434	+ 0.3427	+ 0.0431	− 0.2730
76	.2419	.4122	.3275	.1705	.3362	+ .0070	.2850
77	.2250	.4241	.3090	.1964	.3267	− .0290	.2921
78	.2079	.4352	.2894	.2211	.3143	− .0644	.2942
79	.1908	.4454	.2688	.2443	.2990	− .0990	.2913
80	+ 0.1736	− 0.4548	− 0.2474	+ 0.2659	+ 0.2810	− 0.1321	− 0.2835
81	.1564	.4633	.2251	.2859	.2606	.1635	.2708
82	.1392	.4709	.2020	.3040	.2378	.1927	.2536
83	.1219	.4777	.1783	.3203	.2129	.2193	.2321
84	.1045	.4836	.1539	.3345	.1861	.2431	.2067
85	+ 0.0872	− 0.4886	− 0.1291	+ 0.3468	+ 0.1577	− 0.2638	− 0.1778
86	.0698	.4927	.1038	.3569	.1278	.2810	.1460
87	.0523	.4959	.0781	.3648	.0969	.2947	.1117
88	.0349	.4982	.0522	.3704	.0651	.3045	.0755
89	.0175	.4995	.0262	.3739	.0327	.3105	.0381
90	+ 0.0000	− 0.5000	− 0.0000	+ 0.3750	+ 0.0000	− 0.3125	− 0.0000

TABLE 33.

ELLIPTIC INTEGRALS.

Values of $\int_0^{\frac{\pi}{2}}(1-\sin^2\theta\sin^2\phi)^{\pm\frac{1}{2}}\,d\phi$.

This table gives the values of the integrals between 0 and $\pi/2$ of the function $(1-\sin^2\theta\sin^2\phi)^{\pm\frac{1}{2}}\,d\phi$ for different values of the modulus corresponding to each degree of θ between 0 and 90.

θ	$\int_0^{\frac{\pi}{2}}\frac{d\phi}{(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}}$		$\int_0^{\frac{\pi}{2}}(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}d\phi$		θ	$\int_0^{\frac{\pi}{2}}\frac{d\phi}{(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}}$		$\int_0^{\frac{\pi}{2}}(1-\sin^2\theta\sin^2\phi)^{\frac{1}{2}}d\phi$	
	Number.	Log.	Number.	Log.		Number.	Log.	Number.	Log.
0°	1.5708	0.196120	1.5708	0.196120	45°	1.8541	0.268127	1.3506	0.130541
1	5709	196153	5707	196087	6	8691	271644	3418	127690
2	5713	196252	5703	195988	7	8848	275267	3329	124788
3	5719	196418	5697	195822	8	9011	279001	3238	121836
4	5727	196649	5689	195591	9	9180	282848	3147	118836
5°	1.5738	0.196947	1.5678	0.195293	50°	1.9356	0.286811	1.3055	0.115790
6	5751	197312	5665	194930	1	9539	290895	2963	112698
7	5767	197743	5649	194500	2	9729	295101	2870	109563
8	5785	198241	5632	194004	3	9927	299435	2776	106386
9	5805	198806	5611	193442	4	2.0133	303901	2681	103169
10°	1.5828	0.199438	1.5589	0.192815	55°	2.0347	0.308504	1.2587	0.099915
1	5854	200137	5564	192121	6	0571	313247	2492	096626
2	5882	200904	5537	191362	7	0804	318138	2397	093303
3	5913	201740	5507	190537	8	1047	323182	2301	089950
4	5946	202643	5476	189646	9	1300	328384	2206	086569
15°	1.5981	0.203615	1.5442	0.188690	60°	2.1565	0.333753	1.2111	0.083164
6	6020	204657	5405	187668	1	1842	339295	2015	079738
7	6061	205768	5367	186581	2	2132	345020	1920	076293
8	6105	206948	5326	185428	3	2435	350936	1826	072834
9	6151	208200	5283	184210	4	2754	357053	1732	069364
20°	1.6200	0.209522	1.5238	0.182928	65°	2.3088	0.363384	1.1638	0.065889
1	6252	210916	5191	181580	6	3439	369940	1545	062412
2	6307	212382	5141	180168	7	3809	376736	1453	058937
3	6365	213921	5090	178691	8	4198	383787	1362	055472
4	6426	215533	5037	177150	9	4610	391112	1272	052020
25°	1.6490	0.217219	1.4981	0.175545	70°	2.5046	0.398730	1.1184	0.048589
6	6557	218981	4924	173876	1	5507	406665	1096	045183
7	6627	220818	4864	172144	2	5998	414943	1011	041812
8	6701	222732	4803	170348	3	6521	423596	0927	038481
9	6777	224723	4740	168489	4	7081	432660	0844	035200
30°	1.6858	0.226793	1.4675	0.166567	75°	2.7681	0.442176	1.0764	0.031976
1	6941	228943	4608	164583	6	8327	452196	0686	028819
2	7028	231173	4539	162537	7	9026	462782	0611	025740
3	7119	233485	4469	160429	8	9786	474008	0538	022749
4	7214	235880	4397	158261	9	3.0617	485967	0468	019858
35°	1.7312	0.238359	1.4323	0.156031	80°	3.1534	0.498777	1.0401	0.017081
6	7415	240923	4248	153742	1	2553	512591	0338	014432
7	7522	243575	4171	151393	2	3699	527613	0278	011927
8	7633	246315	4092	148985	3	5004	544120	0223	009584
9	7748	249146	4013	146519	4	6519	562514	0172	007422
40°	1.7868	0.252068	1.3931	0.143995	85°	3.8317	0.583396	1.0127	0.005465
1	7992	255085	3849	141414	6	4.0528	607751	0086	003740
2	8122	258197	3765	138778	7	3387	637355	0053	002278
3	8256	261406	3680	136086	8	7427	676027	0026	001121
4	8396	264716	3594	133340	9	5.4349	735192	0008	000326
45°	1.8541	0.268127	1.3506	0.130541	90°	∞	∞	1.0000	——

TABLE 34.

MOMENTS OF INERTIA, RADII OF GYRATION, AND WEIGHTS.

In each case the axis is supposed to traverse the centre of gravity of the body. The axis is one of symmetry. The mass of a unit of volume is w.

Body.	Axis.	Weight.	Moment of Inertia I_0.	Square of Radius of Gyration ρ_0^2.
Sphere of radius r	Diameter	$\frac{4\pi wr^3}{3}$	$\frac{8\pi wr^5}{15}$	$\frac{2r^2}{5}$
Spheroid of revolution, polar axis $2a$, equatorial diameter $2r$	Polar axis	$\frac{4\pi war^2}{3}$	$\frac{8\pi war^4}{15}$	$\frac{2r^2}{5}$
Ellipsoid, axes $2a$, $2b$, $2c$	Axis $2a$	$\frac{4\pi wabc}{3}$	$\frac{4\pi wabc(b^2+c^2)}{15}$	$\frac{b^2+c^2}{5}$
Spherical shell, external radius r, internal r'	Diameter	$\frac{4\pi w(r^3-r'^3)}{3}$	$\frac{8\pi w(r^5-r'^5)}{15}$	$\frac{2(r^5-r'^5)}{5(r^3-r'^3)}$
Ditto, insensibly thin, radius r, thickness dr	Diameter	$4\pi wr^2dr$	$\frac{8\pi wr^4dr}{3}$	$\frac{2r^2}{3}$
Circular cylinder, length $2a$, radius r	Longitudinal axis $2a$	$2\pi war^2$	πwar^4	$\frac{r^2}{2}$
Elliptic cylinder, length $2a$, transverse axes $2b$, $2c$	Longitudinal axis $2a$	$2\pi wabc$	$\frac{\pi wabc(b^2+c^2)}{2}$	$\frac{b^2+c^2}{4}$
Hollow circular cylinder, length $2a$, external radius r, internal r'	Longitudinal axis $2a$	$2\pi wa(r^2-r'^2)$	$\pi wa(r^4-r'^4)$	$\frac{r^2+r'^2}{2}$
Ditto, insensibly thin, thickness dr	Longitudinal axis $2a$	$4\pi wardr$	$4\pi war^3dr$	r^2
Circular cylinder, length $2a$, radius r	Transverse diameter	$2\pi war^2$	$\frac{\pi war^2(3r^2+4a^2)}{6}$	$\frac{r^2}{4}+\frac{a^2}{3}$
Elliptic cylinder, length $2a$, transverse axes $2a$, $2b$	Transverse axis $2b$	$2\pi wabc$	$\frac{\pi wabc(3c^2+4a^2)}{6}$	$\frac{c^2}{4}+\frac{a^2}{3}$
Hollow circular cylinder, length $2a$, external radius r, internal r'	Transverse diameter	$2\pi wa(r^2-r'^2)$	$\frac{\pi wa}{6}\left\{ 3(r^4-r'^4) + 4a^2(r^2-r'^2) \right\}$	$\frac{r^2+r'^2}{4}+\frac{a^2}{3}$
Ditto, insensibly thin, thickness dr	Transverse diameter	$4\pi wardr$	$\pi wa(2r^3+\frac{4}{3}a^2r)dr$	$\frac{r^2}{2}+\frac{a^2}{3}$
Rectangular prism, dimensions $2a$, $2b$, $2c$	Axis $2a$	$8wabc$	$\frac{8wabc(b^2+c^2)}{3}$	$\frac{b^2+c^2}{3}$
Rhombic prism, length $2a$, diagonals $2b$, $2c$	Axis $2a$	$4wabc$	$\frac{2wabc(b^2+c^2)}{3}$	$\frac{b^2+c^2}{6}$
Ditto	Diagonal $2b$	$4wabc$	$\frac{2wabc(c^2+2a^2)}{3}$	$\frac{c^2}{6}+\frac{a^2}{3}$

(Takeo from Rankine.)

STRENGTH OF MATERIALS.

The strength of most materials varies so that the following figures serve only as a rough indication of the strength of a particular sample.

TABLE 35 (a). — Metals.

Name of Metal.	Tensile strength in pounds per sq. in.
Aluminum wire	30000–40000
Brass wire	50000–150000
Bronze wire, phosphor, hard-drawn	110000–140000
Bronze wire, silicon, hard-drawn	95000–115000
Bronze: Cu, 58.54 parts; Zn, 38.70; Al, 0.21; with 2.55 parts of the alloy, Sn, 29.03, wrought iron, 58.06, ferro-manganese, 12.91	60000–75000
Copper wire, hard-drawn	60000–70000
Gold wire	20000
Iron, cast	13000–33000
" wire, hard-drawn	80000–120000
" " annealed	50000–60000
Lead, cast or drawn	2600–3300
Palladium *	39000
Platinum * wire	50000
Silver * wire	42000
Steel	80000–330000
" wire, maximum	460000
" Specially treated nickel-steel, approx. comp. 0.40 C; 3.25 Ni; treatment secret	250000
" piano wire, 0.033 in. diam.	357000–390000
" piano wire, 0.051 in. diam.	325000–337000
Tin, cast or drawn	4000–5000
Zinc, cast	7000–13000
" drawn	22000–30000

According to Boys, quartz fibres have a tensile strength of between 116000 and 167000 pounds per square inch.

* Authority of Wertheim.

TABLE 35 (b). — Stones.*

Material.	Size of test piece.	Resistance to crushing in pds. per sq. in.
Marble	4 in. cubes	7600–20700
Tufa	2 " "	7700–11600
Brownstone	– – –	7300–23600
Sandstone	4 in. cubes	2400–29300
Granite	4 " "	9700–34000
Limestone	4 " "	6000–25000

* Data furnished by the U. S. Geological Survey.

TABLE 35 (c). — Brick.*

Kind of Brick.	Resistance to crushing in pds. per sq. in.	
	Tested flatwise.	Tested on edge.
Soft burned	1800–4000	1600–3000
Medium burned	4000–6000	3000–4500
Hard burned	6000–8500	4500–6500
Vitrified	8500–25000	6500–20000
Sand-lime	1800–4000	

Brick piers laid up in 1 part Portland cement, 3 of sand, have from 20 to 40 per cent the crushing strength of the brick.

* Data furnished by the U. S. Geological Survey.

TABLE 35 (d). — Concretes.*

Coarse Aggregate.	Proportions by volume. Cement : sand : aggregate.	Size of test piece.	Resistance to crushing in pds. per sq. in.
Sandstone	1 : 5 : 14 to 1 : 1 : 5	12 in. cube	1550–3860
Cinders	1 : 3 : 6 " 1 : 1 : 3	12 " "	790–2050
Limestone	1 : 4 : 8 " 1 : 2 : 4	12 " "	1200–2840
Conglomerate	1 : 6 : 12 " 1 : 2 : 4	12 " "	1080–3830
Trap	1 : 2 : 9 " 1 : 2 : 4	12 " "	820–2960

* Data furnished by the U. S. Geological Survey.

Table 36.

STRENGTH OF MATERIALS.

Average Results of Timber Tests.

The test pieces were SMALL and SELECTED. Endwise compression tests of some of the first lot, made when green and containing over 40 per cent moisture, showed a diminishing in strength of 50 to 75 per cent.

See also Table 37. A particular sample may vary greatly from these data, which can indicate only in a general way the relative values of a kind of timber. Note that the data below are from selected samples and therefore probably high.

The upper lot are from the U. S. Forestry circular No. 15; the lower from the tests made for the 10th U. S. Census.

NAME OF SPECIES.	TRANSVERSE TESTS.		COMPRESSION.		SHEARING.
	Modulus of rupture. lb./sq. in.	Modulus of elasticity. lbs./sq. in.	‖ to grain. lbs./sq. in.	⊥ to grain. lbs./sq. in.	Along the grain. lbs./sq. in.
Long-leaf pine	12,600	2,070,000	8,000	1260	835
Cuban pine	13,600	2,370,000	8,700	1200	770
Short-leaf pine	10,100	1,680,000	6,500	1050	770
Loblolly pine	11,300	2,050,000	7,400	1150	800
White pine	7,900	1,390,000	5,400	700	400
Red pine	9,100	1,620,000	6,700	1000	500
Spruce pine	10,000	1,640,000	7,300	1200	800
Bald cypress	7,900	1,290,000	6,000	800	500
White cedar	6,300	910,000	5,200	700	400
Douglass spruce	7,900	1,680,000	5,700	800	500
White oak	13,100	2,090,000	8,500	2200	1000
Overcup oak	11,300	1,620,000	7,300	1900	1000
Post oak	12,300	2,030,000	7,100	3000	1100
Cow oak	11,500	1,610,000	7,400	1900	900
Red oak	11,400	1,970,000	7,200	2300	1100
Texan oak	13,100	1,860,000	8,100	2000	900
Yellow oak	10,800	1,740,000	7,300	1800	1100
Water oak	12,400	2,000,000	7,800	2000	1100
Willow oak	10,400	1,750,000	7,200	1600	900
Spanish oak	12,000	1,930,000	7,700	1800	900
Shagbark hickory	16,000	2,390,000	9,500	2700	1100
Mockernut hickory	15,200	2,320,000	10,100	3100	1100
Water hickory	12,500	2,080,000	8,400	2400	1000
Bitternut hickory	15,000	2,280,000	9,600	2200	1000
Nutmeg hickory	12,500	1,940,000	8,800	2700	1100
Pecan hickory	15,300	2,530,000	9,100	2800	1200
Pignut hickory	18,700	2,730,000	10,900	3200	1200
White elm	10,300	1,540,000	6,500	1200	800
Cedar elm	13,500	1,700,000	8,000	2100	1300
White ash	10,800	1,640,000	7,200	1900	1100
Green ash	11,600	2,050,000	8,000	1700	1000
Sweet gum	9,500	1,700,000	7,100	1400	800
Poplar	9,400	1,330,000	5,000	1120	
Basswood	8,340	1,172,000	5,190	880	
Ironwood	7,540	1,158,000	5,275	2000	
Sugar maple	16,500	2,250,000	8,800	3600	
White maple	14,640	1,800,000	6,850	2580	
Box elder	7,580	873,000	4,580	1580	
Black walnut	11,900	1,560,000	8,000	2680	
Sycamore	7,000	790,000	6,400	2700	
Hemlock	9,480	1,138,000	5,400	1100	
Red fir	13,270	1,870,000	7,780	1750	
Tamarack	13,150	1,917,000	7,400	1480	
Red cedar	11,800	938,000	6,300	2000	
Cottonwood	10,440	1,450,000	5,000	1100	
Beech	16,200	1,730,000	6,770	2840	

TABLE 37.

UNIT STRESSES FOR STRUCTURAL TIMBER EXPRESSED IN POUNDS PER SQUARE INCH.

Recommended by the Committee on Wooden Bridges and Trestles, American Railway Engineering Association, 1909.

KIND OF TIMBER.	BENDING.			SHEARING.			
	Extreme fibre stress.		Modulus of elasticity.	Parallel to grain.		Longitudinal shear in beams.	
	Average ultimate.	Safe stress.	Average.	Average ultimate.	Safe stress.	Average ultimate.	Safe stress.
Douglass fir	6100	1200	1,510,000	690	170	270	110
Long-leaf pine	6500	1300	1,610,000	720	180	300	120
Short-leaf pine	5600	1100	1,480,000	710	170	330	130
White pine	4400	900	1,130,000	400	100	180	70
Spruce	4800	1000	1,310,000	600	150	170	70
Norway pine	4200	800	1,190,000	590	130	250	100
Tamarack	4600	900	1,220,000	670	170	260	100
Western hemlock	5800	1100	1,480,000	630	160	270*	100
Redwood	5000	900	800,000	300	80	–	–
Bald cypress	4800	900	1,150,000	500	120	–	–
Red cedar	4200	800	860,000	–	–	–	–
White oak	5700	1100	1,150,000	840	210	270	110

KIND OF TIMBER.	COMPRESSION.						Ratio of length of stringer to depth.
	Perpendicular to grain.		Parallel to grain.		For columns under 15 diams. Safe stress.	Formulas for safe stress in long columns over 15 diameters.†	
	Elastic limit.	Safe stress.	Average ultimate.	Safe stress.			
Douglass fir	630	310	3600	1200	900	1200(1–L/60.D)	10
Long-leaf pine	520	260	3800	1300	980	1300(1–L/60.D)	10
Short-leaf pine	340	170	3400	1100	830	1100(1–L/60.D)	10
White pine	290	150	3000	1000	750	1000(1–L/60.D)	10
Spruce	370	180	3200	1100	830	1100(1–L/60.D)	
Norway pine	–	150	2600*	800	600	800(1–L/60.D)	
Tamarack	–	220	3200*	1000	750	1000(1–L/60.D)	–
Western hemlock	440	220	3500	1200	900	1200(1–L/60.D)	–
Redwood	400	150	3300	900	680	900(1–L/60.D)	–
Bald cypress	340	170	3900	1100	830	1100(1–L/60.D)	–
Red cedar	470	230	2800	900	680	900(1–L/60.D)	–
White oak	920	450	3500	1300	980	1300(1–L/60.D)	12

These unit stresses are for a green condition of the timber and are to be used without increasing the live-load stresses for impact.

* Partially air-dry.
† L = length in inches. D = least side in inches.

ELASTIC MODULI.

TABLE 38. — Rigidity Modulus.

If to the four consecutive faces of a cube a tangential stress is applied, opposite in direction on adjacent sides, the modulus of rigidity is obtained by dividing the numerical value of the tangential stress per unit area (kg. per sq. mm.) by the number representing the change of angles on the non-stressed faces, measured in radians.

Substance.	Rigidity Modulus.	Reference.	Substance.	Rigidity Modulus.	Reference.
Aluminum	3350	14	Quartz fibre	2888	20
" cast	2580	5	" "	2380	21
Brass	3550	10	Silver	2960	5
"	3715	11	"	2650	10
" cast, 60 Cu + 12 Sn	3700	5	"	2566	16
Bismuth, slowly cooled	1240	5	" hard-drawn	2816	11
Bronze, cast, 88 Cu + 12 Sn	4060	5	Steel	8290	16
Cadmium, cast	2450	5	" cast	7458	15
Copper, cast	4780	5	" cast, coarse gr.	8070	5
"	4213	18	" silver-	7872	11
"	4450	10	Tin, cast	1730	5
"	4664	19	"	1543	19
Gold	2850	5	Zinc	3880	5
"	3950	14	"	3820	19
Iron, cast	5210	5	Platinum	6630	16
"	6706	15	"	6220	22
"	7975	10	Glass	2350	–
"	6940	7	"	2730	–
"	8108	16	Clay rock	1770	23
"	7505	14	Granite	1280	23
Magnesium, cast	1710	5	Marble	1190	23
Nickel	7820	5	Slate	2290	23
Phosphor bronze	4359	11			

References 1–16, see Table 48.
17 Grätz, Wied. Ann. 28, 1886.
18 Savart, Pogg. Ann. 16, 1829.
19 Kiewiet, Diss. Göttingen, 1886.
20 Threlfall, Philos. Mag. (5) 30, 1890.
21 Boys, Philos. Mag. (5) 30, 1890.
22 Thomson, Lord Kelvin.
23 Gray and Milne.
24 Adams-Coker, Carnegie Publ. No. 46, 1906.

TABLE 39. — Variation of the Rigidity Modulus with the Temperature.

$n_t = n_o (1 - at - \beta t^2 - \gamma t^3)$, where t = temperature Centigrade.

Substance.	n_0	$a 10^6$	$\beta 10^8$	$\gamma 10^{10}$	Authority.
Brass	2652	2158	48	32	Pisati, Nuovo Cimento, 5, 34, 1879.
"	3200	455	36	–	Kohlrausch-Loomis, Pogg. Ann. 141.
Copper	3972	2716	—23	47	Pisati, loc. cit.
"	3900	572	28	–	K and L, loc. cit.
Iron	8108	206	19	—11	Pisati, loc. cit.
"	6940	483	12	–	K and L, loc. cit.
Platinum	6632	111	50	—8	Pisati, loc. cit.
Silver	2566	387	38	11	" " "
Steel	8290	187	59	—9	" " "

$n_t^* = n_{15} [1 - a (t - 15)]$; Horton, Philos. Trans. 204 A, 1905.

Copper	4.37*	a=.00039	Platinum	6.46*	a = .00012	Tin	1.50*	a = .00416
Copper (commercial)	3.80	.00038	Gold	2.45	.00031	Lead	0.80	.00164
Iron	8.26	.00029	Silver	2.67	.00048	Cadmium	2.31	.0058
Steel	8.45	.00026	Aluminum	2.55	.00148	Quartz	3.00	.00012

* Modulus of rigidity in 10^{11} dynes per sq. cm.

Table 40.

ELASTIC MODULI.

Young's Modulus.

$$\text{Young's Modulus} = \frac{\text{Intensity of longitudinal stress (kg. per sq. mm.)}}{\text{Elongation per unit length}}.$$

Substance.	Temp. °C	Young's Modulus.	Reference.	Substance.	Temp. °C.	Young's Modulus.	Reference.
Aluminum	20	7200	1	Nickel-steel, 5½% ni. .	–	19900	13
"	12.3	7462	2	" " 25% " .	–	18600	13
Lead, drawn	15	1803	3	Palladium, annealed .	15	9709	3
" annealed . . .	15	1727	3	Phosphor-bronze . .	–	12010	11
Bronze	–	9194	4	Platinum, drawn .	15	17044	3
Cadmium	–	7070	5	" annealed .	15	15518	3
Delta metal	–	11697	6	"	13.2	16020	2
Iron, drawn	15	20869	3	" drawn . .	10	15989	1
" annealed . . .	15	20794	3	Silver, drawn	15	7357	3
"	0	20310	7	" annealed . .	15	7140	3
"	–	21740	8	Steel wire, drawn . .	15	18810	3
" cast	–	11713	4	" " annealed .	15	17280	3
" soft	15.6	15750	9	Steel, cast, drawn . .	15	19550	3
" drawn	20	19385	1	" " annealed	15	19560	3
" drawn	–	20500	10	" Bessemer . . .	-	21136	4
Gold, drawn	15	8131	3	" puddle		21112	4
" annealed . . .	15	5585	3	" mild	15.5	21700	9
" drawn	12.9	8630	2	" very soft . . .	–	20705	13
Copper, drawn . . .	15	12450	3	" half soft . . .	–	20910	13
" annealed . .	15	10520	3	" hard	–	20600	13
" drawn . . .	0	12140	7	Bismuth	–	3190	5
" drawn . . .	20	12550	1	Zinc, drawn . . .	15	8734	3
" electr. h'd d'n	19.5	13220	9	Tin, drawn	15	4148	3
Brass, drawn	15	8543	3	" cast	–	1700	13
"	0	9810	7				
" drawn	–	10220	11	Glass	–	6000 to 8000	–
"		9930	10				
"		10450	9				
German silver . . .		12094	4	Carbon	–	1500 to 2500	–
" " h'd d'n	–	11550	11				
" " . . .	20	13300	9	Marbles	–	6316	24
Nickel	–	20300	5	Granites	–	5159	24
"	–	22790	12	Basic intrusives . . .	–	8985	24
" hard drawn . .	–	23950	11	Rocks: See Nagaoka,			
"	11.5	21680	2	Philos. Mag. 1900.	.		

1 Slotte, Acta Soc. Fenn. 26, 1899; 29, 1900.
2 Meyer, Wied. Ann. 59, 1896.
3 Wertheim, Ann. chim. phys. (3) 12, 1844.
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15 Wertheim, Pogg. Ann. 78, 1849.
16 Pisati, Nuovo Cimento, 5, 34, 1879.

References 17–19, see Table 47.

Compiled partly from Landolt-Börnstein's Physikalisch-Chemische Tabellen.

COMPRESSIBILITY, HARDNESS, CONTRACTION OF ELEMENTS.

TABLE 41. — Compressibility of the More Important Solid Elements.

Arranged in order of the increasing atomic weights. The numbers give the mean elastic change of volume for one megabar (0.987 atm.) between 100 and 500 megabars, multiplied by 10^6.

Lithium	8.8	Potassium	31.5	Selenium	11.8	Iodine	13.
Carbon	0.5	Calcium	5.5	Bromine	51.8	Cæsium	61.
Sodium	15.4	Chromium	0.7	Rubidium	40.	Platinum	0.21
Magnesium	2.7	Manganese	0.7	Molybdium	0.26	Gold	0.47
Aluminum	1.3	Iron	0.40	Palladium	0.38	Mercury	3.71
Silicon	0.16	Nickel	0.27	Silver	0.84	Thallium	2.6
Red phosphorus	9.0	Copper	0.54	Cadmium	1.9	Lead	2.2
Sulphur	12.5	Zinc	1.5	Tin	1.6	Bismuth	2.8
Chlorine	95.	Arsenic	4.3	Antimony	2.2		

Stull, Zeitschr. Phys Chem 61, 1907.

TABLE 42. — Hardness.

Agate	7.	Brass	3–4.	Iridosmium	7.	Sulphur	1.5–2.5
Alabaster	1.7	Calimine	5.	Iron	4–5.	Stibnite	2.
Alum	2–2.5	Calcite	3.	Kaolin	1.	Serpentine	3–4.
Aluminum	2.	Copper	2.5–3.	Loess (0°)	0.3	Silver	2.5–3.
Amber	2–2.5	Corundum	9.	Magnetite	6.	Steel	5–8.5
Andalusite	7.5	Diamond	10.	Marble	3–4.	Talc	1.
Anthracite	2.2	Dolomite	3.5–4.	Meerschaum	2–3.	Tin	1.5
Antimony	3.3	Feldspar	6.	Mica	2.8	Topaz	8.
Apatite	5.	Flint	7.	Opal	4–6.	Tourmaline	7.3
Aragonite	3.5	Fluorite	4.	Orthoclase	6.	Wax (0°)	0.2
Arsenic	3.5	Galena	2.5	Palladium	4.8	Wood's metal	3.
Asbestos	5.	Garnet	7.	Phosphorbronze	4.		
Asphalt	1–2.	Glass	4.5–6.5	Platinum	4.3		
Augite	6.	Gold	2.5–3.	Plat-iridium	6.5		
Barite	3.3	Graphite	0.5–1.	Pyrite	6.3		
Beryl	7.8	Gypsum	1.6–2.	Quartz	7.		
Bell-metal	4.	Hematite	6.	Rock-salt	2.		
Bismuth	2.5	Hornblende	5.5	Ross' metal	2.5–3.0		
Boric acid	3.	Iridium	6.	Silver chloride	1.3		

From Landolt-Börnstein-Meyerhoffer Tables: Auerbachs, Winklemann, Handb. der Phys. 1891.

TABLE 43. — Relative Hardness of the Elements.

C	10.0	Ru	6.5	Cu	3.0	Au	2.5	Sn	1.8	Li	0.6
B	9.5	Mn	5.0	Sb	3.0	Te	2.3	Sr	1.8	P	0.5
Cr	9.0	Pd	4.8	Al	2.9	Cd	2.0	Ca	1.5	K	0.5
Os	7.0	Fe	4.5	Ag	2.7	S	2.0	Ga	1.5	Na	0.4
Si	7.0	Pt	4.3	Bi	2.5	Se	2.0	Pb	1.5	Rb	0.3
Ir	6.5	As	3.5	Zn	2.5	Mg	2.0	In	1.2	Cs	0.2

Rydberg, Zeitschr. Phys Chem 33, 1900

TABLE 44. — Ratio, ρ, of Transverse Contraction to Longitudinal Extension under Tensile Stress.

(Poisson's Ratio.)

Metal	Pb	Au	Pd	Pt	Ag	Cu	Al	Bi	Sn	Ni	Cd	Fe
ρ	0.45	0.42	0.39	0.39	0.38	0.35	0.34	0.33	0.33	0.31	0.30	0.28

From data from Physikalisch-Technischen Reichsanstalt, 1907.

ρ for: marbles, 0.27; granites, 0.24; basic-intrusives, 0.26; glass, 0.23. Adams-Coker, 1906.

TABLE 45.

ELASTICITY OF CRYSTALS.*

The formulæ were deduced from experiments made on rectangular prismatic bars cut from the crystal. These bars were subjected to cross bending and twisting and the corresponding Elastic Moduli deduced. The symbols $\alpha\ \beta\ \gamma$, $\alpha_1\ \beta_1\ \gamma_1$ and $\alpha_2\ \beta_2\ \gamma_2$ represent the direction cosines of the length, the greater and the less transverse dimensions of the prism with reference to the principal axis of the crystal. E is the modulus for extension or compression, and T is the modulus for torsional rigidity. The moduli are in grams per square centimeter.

Barite.

$$\frac{10^{10}}{E} = 16.13\alpha^4 + 18.51\beta^4 + 10.42\gamma^4 + 2(38.79\beta^2\gamma^2 + 15.21\gamma^2\alpha^2 + 8.88\alpha^2\beta^2)$$

$$\frac{10^{10}}{T} = 69.52\alpha^4 + 117.66\beta^4 + 116.46\gamma^4 + 2(20.16\beta^2\gamma^2 + 85.29\gamma^2\alpha^2 + 127.35\alpha^2\beta^2)$$

Beryl (Emerald).

$$\frac{10^{10}}{E} = 4.325 \sin^4\phi + 4.619 \cos^4\phi + 13.328 \sin^2\phi \cos^2\phi$$

$$\frac{10^{10}}{T} = 15.00 - 3.675 \cos^4\phi_2 - 17.536 \cos^2\phi \cos^2\phi_1$$

where $\phi\ \phi_1\ \phi_2$ are the angles which the length, breadth, and thickness of the specimen make with the principal axis of the crystal.

Fluorspar.

$$\frac{10^{10}}{E} = 13.05 - 6.26\,(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 58.04 - 50.08\,(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Pyrite.

$$\frac{10^{10}}{E} = 5.08 - 2.24\,(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 18.60 - 17.95\,(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Rock salt.

$$\frac{10^{10}}{E} = 33.48 - 9.66\,(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 154.58 - 77.28\,(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Sylvine.

$$\frac{10^{10}}{E} = 75.1 - 48.2\,(\alpha^4 + \beta^4 + \gamma^4)$$

$$\frac{10^{10}}{T} = 306.0 - 192.8\,(\beta^2\gamma^2 + \gamma^2\alpha^2 + \alpha^2\beta^2)$$

Topaz.

$$\frac{10^{10}}{E} = 4.341\alpha^4 + 3.460\beta^4 + 3.771\gamma^4 + 2\,(3.879\beta^2\gamma^2 + 2.856\gamma^2\alpha^2 + 2.39\alpha^2\beta^2)$$

$$\frac{10^{10}}{T} = 14.88\alpha^4 + 16.54\beta^4 + 16.45\gamma^4 + 30.89\beta^2\gamma^2 + 40.89\gamma^2\alpha^2 + 43.51\alpha^2\beta^2$$

Quartz.

$$\frac{10^{10}}{E} = 12.734\,(1-\gamma^2)^2 + 16.693\,(1-\gamma^2)\gamma^2 + 9.705\gamma^4 - 8.460\beta\gamma\,(3\alpha^2 - \beta^2)$$

$$\frac{10^{10}}{T} = 19.665 + 9.060\gamma_2^2 + 22.984\gamma^2\gamma_1^2 - 16.920\,[(\gamma\beta_1 + \beta\gamma_1)\,(3\alpha\alpha_1 - \beta\beta_1) - \beta_2\gamma_2)]$$

* These formulæ are taken from Voigt's papers (Wied. Ann. vols. 31, 34, and 35).

TABLE 46.

ELASTICITY OF CRYSTALS.

Some particular values of the Elastic Moduli are here given. Under E are given moduli for extension or compression in the directions indicated by the subscripts and explained in the notes, and under T the moduli for torsional rigidities round the axes similarly indicated. Moduli in grams per sq. cm.

(a) ISOMETRIC SYSTEM.*

Substance.	E_a	E_b	E_c	T_a	Authority.
Fluorspar	1473×10^6	1008×10^6	910×10^6	345×10^6	Voigt.†
Pyrite	3530×10^6	2530×10^6	2310×10^6	1075×10^6	"
Rock salt	419×10^6	349×10^6	303×10^6	129×10^6	"
"	403×10^6	339×10^6	—	—	Koch.‡
Sylvine	401×10^6	209×10^6	—	—	"
"	372×10^6	196×10^6	—	655×10^6	Voigt.
Sodium chlorate .	405×10^6	319×10^6	—	—	Koch.
Potassium alum . .	181×10^6	199×10^6	—	—	Beckenkamp.§
Chromium alum .	161×10^6	177×10^6	—	—	"
Iron alum	186×10^6	—	—	—	"

(b) ORTHORHOMBIC SYSTEM.‖

Substance.	E_1	E_2	E_3	E_4	E_5	E_6	Authority.
Barite .	620×10^6	540×10^6	959×10^6	376×10^6	702×10^6	740×10^6	Voigt.
Topaz .	2304×10^6	2890×10^6	2652×10^6	2670×10^6	2893×10^6	3180×10^6	"

Substance.	$T_{12} = T_{21}$	$T_{13} = T_{31}$	$T_{23} = T_{32}$	Authority.
Barite	283×10^6	293×10^6	121×10^6	Voigt.
Topaz	1336×10^6	1353×10^6	1104×10^6	"

In the MONOCLINIC SYSTEM, Coromilas (Zeit. für Kryst. vol. 1) gives

Gypsum $\begin{cases} E_{max} = 887 \times 10^6 \text{ at } 21.9^\circ \text{ to the principal axis.} \\ E_{min} = 313 \times 10^6 \text{ at } 75.4^\circ \text{ " " "} \end{cases}$

Mica $\begin{cases} E_{max} = 2213 \times 10^6 \text{ in the principal axis.} \\ E_{min} = 1554 \times 10^6 \text{ at } 45^\circ \text{ to the principal axis.} \end{cases}$

In the HEXAGONAL SYSTEM, Voigt gives measurements on a beryl crystal (emerald). The subscripts indicate inclination in degrees of the axis of stress to the principal axis of the crystal.

$E_0 = 2165 \times 10^6$, $E_{45} = 1796 \times 10^6$, $E_{90} = 2312 \times 10^6$,
$T_0 = 667 \times 10^6$, $T_{90} = 883 \times 10^6$. The smallest cross dimension of the prism experimented on (see Table 82), was in the principal axis for this last case.

In the RHOMBOHEDRAL SYSTEM, Voigt has measured quartz. The subscripts have the same meaning as in the hexagonal system.

$E_0 = 1030 \times 10^6$, $E_{-45} = 1305 \times 10^6$, $E_{+45} = 850 \times 10^6$, $E_{90} = 785 \times 10^6$,
$T_0 = 508 \times 10^6$, $T_{90} = 348 \times 10^6$.

Baumgarten ¶ gives for calcite

$E_0 = 501 \times 10^6$, $E_{-45} = 441 \times 10^6$, $E_{+46} = 772 \times 10^6$, $E_{90} = 790 \times 10^6$.

* In this system the subscript *a* indicates that compression or extension takes place along the crystalline axis, and distortion round the axis. The subscripts *b* and *c* correspond to directions equally inclined to two and normal to the third and equally inclined to all three axes respectively.
† Voigt, "Wied. Ann." 31, p. 474, p. 701, 1887; 34, p. 981, 1888; 36, p. 642, 1888.
‡ Koch, "Wied. Ann." 18, p. 325, 1882.
§ Beckenkamp, "Zeit. für Kryst." vol. 10.
‖ The subscripts 1, 2, 3 indicate that the three principal axes are the axes of stress; 4, 5, 6 that the axes of stress are in the three principal planes at angles of 45° to the corresponding axes.
¶ Baumgarten, "Pogg. Ann." 152, p. 369, 1879.

COMPRESSIBILITY OF GASES.

TABLE 47. — Relative Volumes at Various Pressures and Temperatures, the volume at 0° C and at 1 atmosphere being taken as 1 000 000.

Atm.	Oxygen.			Air.			Nitrogen.			Hydrogen.		
	0°	99°.5	199°.5	0°	99°.4	200°.4	0°	99°.5	199°.6	0°	99°.3	200°.5
100	9265	–	–	9730	–	–	9910	–	–	–	–	–
200	4570	7000	9095	5050	7360	9430	5195	7445	9532	5690	7567	9420
300	3208	4843	6283	3658	5170	6622	3786	5301	6715	4030	5286	6520
400	2629	3830	4900	3036	4170	5240	3142	4265	5331	3207	4147	5075
500	2312	3244	4100	2680	3565	4422	2780	3655	4515	2713	3462	4210
600	2115	2867	3570	2450	3180	3883	2543	3258	3973	2387	3006	3627
700	1979	2610	3202	2288	2904	3502	2374	2980	3589	2149	2680	3212
800	1879	2417	2929	2168	2699	3219	2240	2775	3300	1972	2444	2900
900	1800	2268	2718	2070	2544	3000	2149	2616	3085	1832	2244	2657
1000	1735	2151	–	1992	2415	2828	2068		–	1720	2093	–

Amagat: C. R. 111, p. 871, 1890; Ann. chim. phys. (6) 29, pp. 68 and 505, 1893.

TABLE 48. — Ethylene.

pv at 0° C and 1 atm. = 1.

Atm.	0°	10°	20°	30°	40°	60°	80°	100°	137°.5	198°.5
46	–	0.562	0.684	–	–	–	–	–	–	
48	–	0.508	–	–	–	–	–	–	–	–
50	0.176	0.420	0.629	0.731	0.814	0.954	1.077	1.192	1.374	1.652
52	–	0.240	0.598	–	–	–	–	-	–	–
54	–	0.229	0.561	–	–	–	–	–	–	–
56	–	0.227	0.524	–	–	–	–	–	–	-
100	0.310	0.331	0.360	0.403	0.471	0.668	0.847	1.005	1.247	1.580
150	0.441	0.459	0.485	0.515	0.551	0.649	0.776	0.924	1.178	1.540
200	0.565	0.585	0.610	0.638	0.669	0.744	0.838	0.946	1.174	1.537
300	0.806	0.827	0.852	0.878	0.908	0.972	1.048	1.133	1.310	1.628
500	1.256	1.280	1.308	1.337	1.367	1.431	1.500	1.578	1.721	1.985
1000	2.289	2.321	2.354	2.387	2.422	2.493	2.566	2.643	2.798	–

Amagat, C. R. 111, p. 871, 1890; 116, p. 946, 1893.

TABLE 49. — Ethylene.

Pressure in meters of mercury.	Relative values of *pv* at —									
	16°.3	20°.3	30°.1	40°.0	50°.0	60°.0	70°.0	79°.9	89°.9	100°.0
30	1950	2055	2220	2410	2580	2715	2865	2970	3090	3225
60	810	900	1190	1535	1875	2100	2310	2500	2680	2860
90	1065	1115	1195	1325	1510	1710	1930	2160	2375	2565
120	1325	1370	1440	1540	1660	1780	1950	2115	2305	2470
150	1590	1625	1690	1785	1880	1990	2125	2250	2390	2540
180	1855	1890	1945	2035	2130	2225	2340	2450	2565	2700
210	2110	2145	2200	2285	2375	2470	2565	2680	2790	2910
240	2360	2395	2450	2540	2625	2720	2810	2910	3015	3125
270	2610	2640	2710	2790	2875	2965	3060	3150	3240	3345
300	2860	2890	2960	3040	3125	3215	3300	3380	3470	3560
320	3035	3065	3125	3200	3285	3375	3470	3545	3625	3710

Amagat, Ann. chim. phys. (5) 22, p. 353, 1881.

COMPRESSIBILITY OF GASES.

TABLE 50. — Carbon Dioxide.

Pressure in metres of mercury.	Relative values of pv at —								
	18°.2	35°.1	40°.2	50°.0	60°.0	70°.0	80°.0	90°.0	100°.0
30	liquid	2360	2460	2590	2730	2870	2995	3120	3225
50	–	1725	1900	2145	2330	2525	2685	2845	2980
80	625	750	825	1200	1650	1975	2225	2440	2635
110	825	930	980	1090	1275	1550	1845	2105	2325
140	1020	1120	1175	1250	1360	1525	1715	1950	2160
170	1210	1310	1360	1430	1520	1645	1780	1975	2135
200	1405	1500	1550	1615	1705	1810	1930	2075	2215
230	1590	1690	1730	1800	1890	1990	2090	2210	2340
260	1770	1870	1920	1985	2070	2166	2265	2375	2490
290	1950	2060	2100	2170	2260	2340	2440	2550	2655
320	2135	2240	2280	2360	2440	2525	2620	2725	2830

Atm.	Relative values of pv; pv at 0° C. and 1 atm. = 1.										
	0°	10°	20°	30°	40°	60°	80°	100°	137°	198°	258°
50	0.105	0.114	0.680	0.775	0.750	0.984	1.096	1.206	1.380	·	–
100	0.202	0.213	0.229	0.255	0.309	0.661	0.873	1.030	1.259	1.582	1.847
150	0.295	0.309	0.326	0.346	0.377	0.485	0.681	0.878	1.159	1.530	1.818
300	0.559	0.578	0.599	0.623	0.649	0.710	0.790	0.890	1.108	1.493	1.820
500	0.891	0.913	0.938	0.963	0.990	1.054	1.124	1.201	1.362	1.678	–
1000	1.656	1.685	1.716	1.748	1.780	1.848	1.921	1.999	–	–	–

Amagat, C. R. 111, p. 871, 1890; Ann. chim. phys. (5) 22, p. 353, 1881; (6) 29, pp. 68 and 405, 1893.

TABLE 51. — Compressibility of Gases.

Gas.	$\frac{p.v. (\frac{1}{2} \text{ atm.})}{p_0 v_0 (1 \text{ atm.})}$	$\frac{1}{p.v.} \frac{d(p.v.)}{dp} = a.$	t	a $t = 0$	Density. O = 32, 0°C. P = 76cm	Density. Very small pressure.
O_2	1.00038	— .00076	11.2°	— .00094	32.	32.
H_2	0.99974	+ .00052	10.7	+ .00053	2.015 (16°)	2.0173
N_2	1.00015	— .00030	14.9	— .00056	28.005	28.016
CO	1.00026	— .00052	13.8	— .00081	28.000	28.003
CO_2	1.00279	— .00558	15.0	— .00668	44.268	44.014
N_2O	1.00327	— .00654	11.0	— .00747	44.285	43.996
Air	1.00026	— .00046	11.4	–	–	–
NH_3	1.00632	–	–	–	–	–

Rayleigh, Zeitschr. Phys. Chem. 52, p. 705, 1905.

TABLE 52. — Compressibility of Air and Oxygen between 18° and 22° C.

Pressures in metres of mercury, pv, relative.

Air	p	24.07	34.90	45.24	55.30	64.00	72.16	84.22	101.47	214.54	304.04
	pv	26968	26908	26791	26789	26778	26792	26840	27041	29585	32488
O_2	p	24.07	34.89	–	55.50	64.07	72.15	84.19	101.06	214.52	303.03
	pv	26843	26614	–	26185	26050	25858	25745	25639	26536	28756

Amagat, C. R. 1879.

RELATION BETWEEN PRESSURE, TEMPERATURE AND VOLUME OF SULPHUR DIOXIDE AND AMMONIA.*

TABLE 53.—Sulphur Dioxide.

Original volume 100000 under one atmosphere of pressure and the temperature of the experiments as indicated at the top of the different columns.

Pressure in Atmos.	Corresponding Volume for Experiments at Temperature —		
	58°.0	99°.6	183°.2
10	8560	9440	-
12	6360	7800	-
14	4040	6420	-
16	-	5310	-
18	-	4405	-
20	-	4030	-
24		3345	-
28		2780	3180
32	-	2305	2640
36	-	1935	2260
40	-	1450	2040
50	-	-	1640
60	-	-	1375
70	-	-	1130
80	-		930
90	-		790
100	-	-	680
120	-		545
140	-		430
160	-		325

Volume.	Pressure in Atmospheres for Experiments at Temperature —		
	58°.0	99°.6	183°.2
10000	-	9.60	-
9000	9.60	10.35	-
8000	10.40	11.85	-
7000	11.55	13.05	-
6000	12.30	14.70	-
5000	13.15	16.70	-
4000	14.00	20.15	-
3500	14.40	23.00	-
3000	-	26.40	29.10
2500	-	30.15	33.25
2000		35.20	40.95
1500	-	39.60	55.20
1000	-	-	76.00
500	-	-	117.20

TABLE 54.—Ammonia.

Original volume 100000 under one atmosphere of pressure and the temperature of the experiments as indicated at the top of the different columns.

Pressure in Atmos.	Corresponding Volume for Experiments at Temperature —		
	46°.6	99°.6	183°.6
10	9500	-	-
12.5	7245	7635	-
15	5880	6305	-
20	-	4645	4875
25	-	3560	3835
30	-	2875	3185
35	-	2440	2680
40	-	2080	2345
45	-	1795	2035
50	-	1490	1775
55	-	1250	1590
60	-	975	1450
70	-	-	1245
80	-	-	1125
90	-	-	1035
100	-	-	950

Volume.	Pressure in Atmospheres for Experiments at Temperature —			
	30°.2	46°.6	99°.6	183°.0
10000	8.85	9.50		-
9000	9.60	10.45		-
8000	10.40	11.50	12.00	-
7000	11.05	13.00	13.60	-
6000	11.80	14.75	15.55	-
5000	12.00	16.60	18.60	19.50
4000	-	18.35	22.70	24.00
3500	-	18.30	25.40	27.20
3000		-	29.20	31.50
2500	-	-	34.25	37.35
2000	-	-	41.45	45.50
1500	-	-	49.70	58.00
1000	-	-	59.65	93.60

* From the experiments of Roth, "Wied. Ann." vol. 11, 1880.

COMPRESSIBILITY OF LIQUIDS.

If V_1 is the volume under pressure p_1 atmospheres at $t°C$, and V_2 is volume at pressure p_2 and the same temperature, then the compressibility coefficient may be defined at that temperature as:

$$\beta_t = \frac{1}{V_1} \cdot \frac{V_1 - V_2}{p_2 - p_1}.$$

In absolute units (referred to megadynes) the coefficient is $\frac{1}{1.0137}\beta_t$.

Substance.	t.	Pressures.	$\beta \cdot 10^6$	Reference.	Substance.	t.	Pressures.	$\beta \cdot 10^6$	Reference.
	°					°			
Acetone	0.00	1–500	82	1	Methyl alcohol	100.	8.68–37.3	221	3
"	0.00	500–1000	59	"	" "	18.10	8	120	2
"	0.00	1000–1500	47	"	Nitric acid	20.3	1–32	338	11
"	99.5	8.94–36.5	276	3	Oils: Almond	17.	–	55	8
Benzole	5.95	8	83	2	Olive	20.5	–	63	"
"	17.9	8	92	"	Paraffin	14.8	–	63	6
"	15.4	1–4	87	4	Petroleum	16.5	–	70	12
"	78.8	1–4	126	"	Rock	19.4	–	75	8
Carbon bisulphide	0.00	1–500	66	1	Rape-seed	20.3	–	60	"
" "	0.00	500–1000	53	"	Turpentin	19.7	–	79	"
" "	0.00	1000–1500	43	"	Toluene	10.	–	79	13
" "	49.2	1000–1500	51	"	"	100.	–	150	"
Chloroform	0.	–	101	5	Xylene	10.	–	74	15
"	20.	–	128	"	"	100.	–	132	"
"	40.	–	162	"	Paraffins: C_6H_{14}	23.	0–1	159	14
"	60.	–	204	"	C_7H_{16}	"	"	134	"
"	100.	8–9	211	3	C_8H_{18}	"	"	121	"
"	100.	19–34	206	"	C_9H_{20}	"	"	113	"
Collodium	14.8		97	6	$C_{10}H_{22}$	"	"	105	"
Ethyl alcohol	28.	150–200	86	7	$C_{12}H_{26}$	"	"	92	"
" "	28.	150–400	81	"	$C_{14}H_{30}$	"	"	83	"
" "	65.	150–200	110	"	$C_{16}H_{34}$	"	"	75	"
" "	65.	150–400	100	"	Water	0.	1–25	52.5	1
" "	100.	150–200	168	"	"	10.	"	50.0	"
" "	100.	150–400	132	"	"	20.	"	49.1	"
" "	185.	150–200	320	"	"	0.	25–50	51.6	"
" "	185.	150–400	245	"	"	10.	"	49.2	"
" "	310.	150–200	4200	"	"	20.	"	47.6	"
" "	310.	150–400	1530	"	"	0.	1–100	51.1	"
" "	0.	1–50	96	1	"	10.	"	48.3	"
" "	20.	1–50	112	"	"	20.	"	46.8	"
" "	40.	1–50	125	"	"	50.	"	44.9	"
" "	0.	100–200	85	"	"	100.	"	47.8	"
" "	0.	300–400	73	"	"	0.	100–200	49.2	"
" "	20.	300–400	78	"	"	10.	"	46.1	"
" "	40.	300–400	87	"	"	20.	"	44.2	"
" "	0.	500–600	64	"	"	50.	"	42.5	"
" "	0.	700–800	56	"	"	100.	"	46.8	"
" "	20.	700–800	62	"	"	0.	1–500	47.5	"
" "	40.	700–800	65	"	"	20.4	"	43.4	"
" "	0.	900–1000	52	"	"	48.85	"	41.6	"
Ethyl chloride	11.	8.5–34.2	138	3	"	0.	500–1000	41.6	"
" "	15.2	8.7–37.2	153	"	"	0.	1000–1500	35.8	"
" "	61.5	12.6–34.4	256	"	"	20.4	"	33.8	"
" "	99.0	12.8–34.5	495	"	"	48.85	"	32.5	"
Glycerine	20.5	–	25	8	"	0.	1500–2000	32.4	"
"	14.8	–	22	6	"	0.	2000–2500	29.2	"
Mercury	0.	–	3.92	9	"	0.	2500–3000	26.1	"
"	0.	–	3.90	10	"	48.85	"	25.4	"
Methyl alcohol	14.7	8.50–37.1	104	3					

For references see page 80.

COMPRESSIBILITY AND BULK MODULI OF SOLIDS.

Solid.		Compression per unit volume per atmo. × 10^6.	Authority.	Calculated values of bulk modulus in —	
				Grams per sq. cm.	Pounds per sq. in.
Crystals:	Barite	1.93	Voigt	535 × 10^6	7.61 × 10^6
	Beryl	0.747	"	1384 "	19.68 "
	Fluorspar	1.20	"	860 "	12.24 "
	Pyrites	1.14	"	906 "	12.89 "
	Quartz	2.67	"	387 "	5.50 "
	Rock salt	4.20*	"	246 "	3.50 "
	Sylvine	7.45*	"	138 "	1.97 "
	Topaz	0.61	"	1694 "	24.11 "
	Tourmaline	0.113	"	9140 "	130.10 "
Brass		0.95	Amagat	1090 "	15.48 "
Copper		0.86	Buchanan	1202 "	17.10 "
Delta metal		1.02	Amagat	1012 "	14.41 "
Lead		2.76	"	374 "	5.32 "
Steel		0.68	"	1518 "	21.61 "
Glass		2.2–2.9	"	405 "	5.76 "

NOTE: Winklemann, Schott, and Straulel (Wied Ann. 61, 63, 1897; 68, 1899) give the following coefficients (among others) for various Jena glasses in terms of the volume decrease divided by the increase of pressure expressed in kilograms per square millimeter:

The following values in cm^2 / Kg of 10^6 × Compressibility are given for the corresponding temperatures by Grüneisen Ann. der Phys. 33, p. 65, 1910.

Al. — 191°, 1.32; 17°, 1.46; 125°, 1.70. Fe. — 190°, 0.61; 18°, 0.63; 165°, 0.67.
Cu. — 191°, 0.72; 17°, 0.77; 165°, 0.83. Ag. — 191°, 0.71; 16°, 0.76; 166°, 0.86.
Pt. — 189°, 0.37; 17°, 0.39; 164°, 0.40. Pb. — 191°, (2.5); 14°, (3.2)

No.	Glass.	Compressibility.	No.	Glass.	Compressibility
665	. . . .	7520	2154	Kalibleisilicat	3660
1299	Barytborosilicat	5800	S 208	Heaviest Bleisilicat	3550
16	Natronkalkzinksilicat	4530	500	Very Heavy "	3510
278	. . . .	3790	S 196	Tonerdborat with sodium, baryte	3470

* Röntgen and Schneider by piezometric experiments obtained 5.0 × 10^{-6} for rock salt, and 5.6 × 10^{-6} for sylvine (Wied. Ann., vol. 31).

References to Tables 55 and 56.

Liquids (Table 55):
1 Amagat, Ann. chim. phys. (6) 29, 1893.
2 Röntgen, Wied. Ann. 44, p. 1, 1891.
3 Amagat, C. R. 68, p. 1170, 1869; Ann. chim. phys. (5) 28, 1883.
4 Pagliani-Palazzo, Mem. Acad. Lin. (3) 19, 1883.
5 Grimaldi, Zeitschr. Phys. Chem. 1, 1887.
6 de Metz, Wied. Ann. 41, p. 663, 1890; 47, p. 706, 1892.
7 Barus, Sill. Journ. 39, p. 478, 1890; 41, 1891; Bull. U.S. Geol. Surv. 1892.
8 Quincke, Wied. Ann. 19, p. 401, 1883.
9 Amagat, Ann. chim. phys. (6) 22, p. 95, 1891.
10 Aimé, Ann. chim. phys. (3) 8, p. 268, 1843.
11 Colladon-Sturm, Pogg. Ann. 12, p. 39, 1828.
12 Martini.
13 de Heen, Bull. Acad. Roy. Belg. (3) 9, 1885.
14 Bartoli, Rend Lomb. (2) 28, 29, 1896.
15 Protz, Ann. der Phys. (4) 31, p. 127, 1910.
See also Bridgman, Proc. Ann. Acad. 48, p. 309, 1912 (H_2O) 49, p. 3, 1913 (alcohols, etc.); 49, p. 627, 1914 (high pressure technique).

Solids (Table 56):
Amagat, C. R. 108, p. 228, 1889; J. de Phys. (2) 8, p. 197, 1889.
Buchanan, Proc. Roy. Soc. Edinb. 10, 1880.
Voigt, Wied. Ann. 31, 1887; 34, 1888, 36, 1888.

TABLE 57.

SPECIFIC GRAVITIES CORRESPONDING TO THE BAUMÉ SCALE.

The specific gravities are for 15.56°C (60°F) referred to water at the same temperature as unity. For specific gravities less than unity the values are calculated from the formula:

$$\text{Degrees Baumé} = \frac{140}{\text{Specific Gravity}} - 130.$$

For specific gravities greater than unity from:

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{Specific Gravity}}.$$

Specific Gravities less than 1.

Specific Gravity.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	Degrees Baumé.									
0.60	103.33	99.51	95.81	92.22	88.75	85.38	82.12	78.95	75.88	72.90
.70	70.00	67.18	64.44	61.78	59.19	56.67	54.21	51.82	49.49	47.22
.80	45.00	42.84	40.73	38.68	36.67	34.71	32.79	30.92	29.09	27.30
.90	25.56	23.85	22.17	20.54	18.94	17.37	15.83	14.33	12.86	11.41
1.00	10.00									

Specific Gravities greater than 1.

Specific Gravity.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	Degrees Baumé.									
1.00	0.00	1.44	2.84	4.22	5.58	6.91	8.21	9.49	10.74	11.97
1.10	13.18	14.37	15.54	16.68	17.81	18.91	20.00	21.07	22.12	23.15
1.20	24.17	25.16	26.15	27.11	28.06	29.00	29.92	30.83	31.72	32.60
1.30	33.46	34.31	35.15	35.98	36.79	37.59	38.38	39.16	39.93	40.68
1.40	41.43	42.16	42.89	43.60	44.31	45.00	45.68	46.36	47.03	47.68
1.50	48.33	48.97	49.60	50.23	50.84	51.45	52.05	52.64	53.23	53.80
1.60	54.38	54.94	55.49	56.04	56.58	57.12	57.65	58.17	58.69	59.20
1.70	59.71	60.20	60.70	61.18	61.67	62.14	62.61	63.08	63.54	63.99
1.80	64.44	64.89	65.33	65.76	66.20	66.62				

REDUCTIONS OF WEIGHINGS IN AIR TO VACUO.

TABLE 58.

When the weight M in grams of a body is determined in air, a correction is necessary for the buoyancy of the air equal to M δ (1/d — 1/d_1) where δ = the density (wt. of 1 ccm in grams = 0.0012) of the air during the weighing, d the density of the body, d_1 that of the weights. δ for various barometric values and humidities may be determined from Tables 153 to 155. The following table is computed for δ = 0.0012. The corrected weight = M + kM/1000.

Density of body weighed d.	Correction factor, k. Pt. Ir. weights d_1 = 21.5.	Brass weights 8.4.	Quartz or Al. weights 2.65.	Density of body weighed d.	Correction factor, k. Pt. Ir. weights d_1 = 21.5.	Brass weights 8.4.	Quartz or Al. weights 2.65.
.5	+ 2.34	+ 2.26	+ 1.95	1.6	+ 0.69	+ 0.61	+ 0.30
.6	+ 1.94	+ 1.86	+ 1.55	1.7	+ .65	+ .56	+ .25
.7	+ 1.66	+ 1.57	+ 1.26	1.8	+ .62	+ .52	+ .21
.75	+ 1.55	+ 1.46	+ 1.15	1.9	+ .58	+ .49	+ .18
.80	+ 1.44	+ 1.36	+ 1.05	2.0	+ .54	+ .46	+ .15
.85	+ 1.36	+ 1.27	+ 0.96	2.5	+ .43	+ .34	+ .03
.90	+ 1.28	+ 1.19	+ .88	3.0	+ .34	+ .26	— .05
.95	+ 1.21	+ 1.12	+ .81	4.0	+ .24	+ .16	— .15
1.00	+ 1.14	+ 1.06	+ .75	6.0	+ .14	+ .06	— .25
1.1	+ 1.04	+ 0.95	+ .64	8.0	+ .09	+ .01	— .30
1.2	+ 0.94	+ .86	+ .55	10.0	+ .06	— .02	— .33
1.3	+ .87	+ .78	+ .47	15.0	+ .03	— .06	— .37
1.4	+ .80	+ .71	+ .40	20.0	+ .004	— .08	— .39
1.5	+ .75	+ .66	+ .35	22.0	— .001	— .09	— .40

TABLE 59. — Reductions of Densities in Air to Vacuo.

(This correction may be accomplished through the use of the above table for each separate weighing.)

If s is the density of the substance as calculated from the uncorrected weights, S its true density, and L the true density of the liquid used, then the vacuum correction to be applied to the uncorrected density, s, is 0.0012 (1 — s/L).

Let W_s = uncorrected weight of substance, W_l = uncorrected weight of the liquid displaced by the substance, then by definition, s = LW_s/W_l. Assuming D to be the density of the balance of weights, $W_s\{1 + 0.0012\,(1/S - 1/D)\}$ and $W_l\{1 + 0.0012\,(1/L - 1/D)\}$ are the true weights of the substance and liquid respectively (assuming that the weighings are made under normal atmospheric corrections, so that the weight of 1 cc. of air is 0.0012 gram).

Then the true density $$S = \frac{W_s\{1 + 0.0012\,(1/S - 1/D)\}}{W_l\{1 + 0.0012\,(1/L - 1/D)\}}L.$$

But from above W_s/W_l = s/L, and since L is always large compared with 0.0012,

$$S - s = 0.0012\,(1 - s/L).$$

The values of 0.0012 (1 — s/L) for densities up to 20 and for liquids of density 1 (water), 0.852 (xylene) and 13.55 (mercury) follow:

(See reference below for discussion of density determinations).

Density of substance s.	Corrections. L = 1 Water.	L = 0.852 Xylene.	L = 13.55 Mercury.	Density of substance s	Corrections. L = 1 Water.	L = 13.55 Mercury.
0.8	+ 0.00024	-	-	11.	— 0.0120	+ 0.0002
0.9	+ .00012			12.	— .0132	+ .0001
1.	0.0000	— 0.0002	+ 0.0011	13.	— .0144	0.0000
2.	— .0012	— .0016	+ .0010	14.	— .0156	0.0000
3.	— .0024	— .0030	+ .0009	15.	— .0168	— .0001
4.	— .0036	— .0044	+ .0008	16.	— .0180	— .0002
5.	— .0048	— .0058	+ .0008	17.	— .0192	— .0003
6.	— .0060	— .0073	+ .0007	18.	— .0204	— .0004
7.	— .0072	— .0087	+ .0006	19.	— .0216	— .0005
8.	— .0084	— .0101	+ .0005	20.	— .0228	— .0006
9.	— .0096	— .0115	+ .0004			
10.	— .0108	— .0129	+ .0003			

Johnston and Adams, J. Am. Chem. Soc. 34, p. 563, 1912.

Table 60.

DENSITY OR MASS IN GRAMS PER CUBIC CENTIMETER OF THE ELEMENTS, LIQUID OR SOLID.

N. B. The density of a specimen may depend considerably on its state and previous treatment.

Element.	Physical State.	Grams per cu. cm.*	Temperature.†	Authority.
Aluminum	cast	2.56–2.58		
"	wrought	2.65–2.80		
"	pure	2.58	4	Mallet, 1882.
Antimony	vacuo-distilled	6.618	20	Kahlbaum, 1902.
"	ditto-compressed	6.691	20	"
"	amorphous	6.22		Hérard.
Argon	liquid	1.3845	—183	Baly-Donnan.
"	"	1.4233	—189	" "
Arsenic	crystallized	5.73	14	
"	amorph. br.-black	3.70		Geuther.
"	yellow	3.88		Linck.
Barium		3.78		Guntz.
Bismuth	solid	9.70–9.90		
"	electrolytic	9.747		Classen, 1890.
"	vacuo-distilled	9.781	20	Kahlbaum, 1902.
"	liquid	10.00	271	Vincentini-Omodei.
"	solid	9.67	271	" "
Boron	crystal	2.535		Wigand.
"	amorph. pure	2.45		Moissan.
Bromine	liquid	3.12		Richards-Stull.
Cadmium	cast	8.54–8.57		
"	wrought	8.67		
"	vacuo-distilled	8.648	20	Kahlbaum, 1902.
"	solid	8.37	318	Vincentini-Omodei.
"	liquid	7.99	318	" "
Cæsium		1.873	20	Richards-Brink.
Calcium		1.54		Brink.
Carbon	diamond	3.52		Wigand.
"	graphite	2.25		"
Cerium	electrolytic	6.79		Muthmann-Weiss.
"	pure	7.02		" "
Chlorine	liquid	1.507	—33.6	Drugman-Ramsay.
Chromium		6.52–6.73		
"	pure	6.92	20	Moissan.
Cobalt		8.71	21	Tilden, Ch. C. 1898.
Columbium		8.4	15	Muthmann-Weiss.
Copper	cast	8.30–8.95		
"	drawn	8.93–8.95		
"	wrought	8.85–8.95		
"	electrolytic	8.88–8.95		
"	vacuo-distilled	8.9326	20	Kahlbaum, 1902.
"	ditto-compressed	8.9376	20	" "
"	liquid	8.217		Roberts-Wrightson.
Erbium		4.77		St. Meyer, Z. Ph. Ch. 37.
Fluorine	liquid	1.14	—200	Moissan-Dewar.
Gallium		5.93	23	de Boisbaudran.
Germanium		5.46	20	Winkler.
Glucinum		1.85		Humpidge.
Gold	cast	19.3		
"	wrought	19.33		
"	vacuo-distilled	18.88	20	Kahlbaum, 1902.
"	ditto-compressed	19.27	20	"
Helium	liquid	0.15	—269	Onnes, 1908.
Hydrogen	liquid	0.070	—252	Dewar, Ch. News, 1904.
Indium		7.28		Richards.

* To reduce to pounds per cu. ft. multiply by 62.4.
† Where the temperature is not given, ordinary atmospheric temperature is understood.

Compiled from Clarke's Constants of Nature, Landolt-Börnstein-Meyerhoffer's Tables, and other sources. Where no authority is stated, the values are mostly means from various sources.

TABLE 60 (*continued*).

DENSITY OR MASS IN GRAMS PER CUBIC CENTIMETER OF THE ELEMENTS, LIQUID OR SOLID.

Element.	Physical State	Grams per cu. cm.*	Temperature.†	Authority.
Iridium		22.42	17	Deville-Debray
Iodine		4.940	20	Richards-Stull
Iron	pure	7.85–7.88		
"	gray cast	7.03–7.13		
"	white cast	7.58–7.73		
"	wrought	7.80–7.90		
"	liquid	6.88		Roberts-Austen
"	steel	7.60–7.80		
Krypton	liquid	2.16	—146	Ramsay-Travers
Lanthanum		6.15		Muthmann-Weiss
Lead	cast	11.37	24	Reich
"	wrought	11.36	24	"
"	solid	11.005	325	Vincentini-Omodei
"	liquid	10.645	325	" "
"	vacuo-distilled	11.342	20	Kahlbaum, 1902
"	ditto-compressed	11.347	20	" "
Lithium		0.534	20	Richards-Brink, '07
Magnesium		1.741		Voigt
Manganese		7.42		Prelinger
Mercury	liquid	13.596	0	Regnault, Volkmann
"	"	13.546	20	
"	"	13.690	—38.8	Vincentini-Omodei
"	solid	14.193	—38.8	Mallet
"	"	14.383	—188	Dewar, 1902
Molybdenum		9.01		Moissan
Neodymium		6.96		Muthmann-Weiss
Nickel		8.60–8.90		
Nitrogen	liquid	0.810	—195	Baly-Donnan, 1902
"	"	0.854	—205	" " "
Osmium		22.5		Deville-Debray
Oxygen	liquid	1.14	—184	
Palladium		12.16		Richards-Stull
Phosphorus	white	1.83		
"	red	2.20		
"	metallic	2.34	15	Hittorf
Platinum		21.37	20	Richards-Stull
Potassium		0.870	20	Richards-Brink, '07
"	solid	0.851	62.1	Vincentini-Omodei
"	liquid	0.830	62.1	" "
Præsodymium		6.475		Muthmann-Weiss
Rhodium		12.44		Holborn Henning
Rubidium		1.532	20	Richards-Brink, '07
Ruthenium		12.06	0	Toby
Samarium		7.7–7.8		Muthmann-Weiss
Selenium		4.3–4.8		
Silicon	cryst.	2.42	20	Richards-Stull-Brink
"	amorph.	2.35	15	Vigoroux
Silver	cast	10.42–10.53		
"	wrought	10.6		
"	vacuo-distilled	10.492	20	Kahlbaum, 1902
"	ditto-compressed	10.503	20	" "
"	liquid	9.51		Wrightson
Sodium		0.9712	20	Richards-Brink, '07
"	solid	0.9519	97.6	Vincentini-Omodei
"	liquid	0.9287	97.6	" "
"		1.0066	—188	Dewar
Strontium		2.50–2.58		Matthiessen
Sulphur		2.0–2.1		
"	liquid	1.811	113	Vincentini-Omodei

* To reduce to pounds per cubic ft. multiply by 62.4.
† Where the temperature is not given, ordinary atmosphere temperature is understood.

TABLE 60 (*continued*). — Density or Mass in grams per cubic centimeter and pounds per cubic foot of the elements, liquid or solid.

Element.	Physical State.	Grams per cu. cm.	Temperature.	Authority.
Tantalum		16.6		
Tellurium	crystallized	6.25		
"	amorphous	6.02	20	Beljankin.
Thallium		11.86		Richards-Stull.
Thorium		12.16	17	Bolton.
Tin	white, cast	7.29		Matthiessen.
"	" wrought	7.30		
"	" crystallized	6.97–7.18		
"	" solid	7.184	226	Vincentini-Omodei
"	" liquid	6.99	226	Vincentini-Omodei
"	gray	5.8		
Titanium		4.5	18	Mixter.
Tungsten		18.6–19.1		
Uranium		18.7	13	Zimmermann.
Vanadium		5.69		Ruff-Martin.
Xenon	liquid	3.52	109	Ramsay-Travers.
Yttrium		3.80		St. Meyer.
Zinc	cast	7.04–7.16		
"	wrought	7.19		
"	vacuo-distilled	6.92	20	Kahlbaum, 1902.
"	ditto-compressed	7.13	20	" "
"	liquid	6.48		Roberts-Wrightson.
Zirconium		6.44		

TABLE 61. — Mass in grams per cubic centimeter and in pounds per cubic foot of different kinds of wood.

The wood is supposed to be seasoned and of average dryness.

Wood.	Grams per cubic centimeter.	Pounds per cubic foot.
Alder	0.42–0.68	26–42
Apple	0.66–0.84	41–52
Ash	0.65–0.85	40–53
Bamboo	0.31–0.40	19–25
Basswood. See Linden.		
Beech	0.70–0.90	43–56
Blue gum	1.00	62
Birch	0.51–0.77	32–48
Box	0.95–1.16	59–72
Bullet-tree	1.05	65
Butternut	0.38	24
Cedar	0.49–0.57	30–35
Cherry	0.70–0.90	43–56
Cork	0.22–0.26	14–16
Dogwood	0.76	47
Ebony	1.11–1.33	69–83
Elm	0.54–0.60	34–37
Fir or Pine, American White	0.35–0.50	22–31
" Larch	0.50–0.56	31–35
" Pitch	0.83–0.85	52–53
" Red	0.48–0.70	30–44
" Scotch	0.43–0.53	27–33
" Spruce	0.48–0.70	30–44
" Yellow	0.37–0.60	23–37
Greenheart	0.93–1.04	58–65
Hazel	0.60–0.80	37–49
Hickory	0.60–0.93	37–58
Holly	0.76	47
Iron-bark	1.03	64
Juniper	0.56	35
Laburnum	0.92	57
Lancewood	0.68–1.00	42–62
Lignum vitæ	1.17–1.33	73–83
Linden or Lime-tree	0.32–0.59	20–37
Locust	0.67–0.71	42–44
Logwood	.91	57
Mahogany, Honduras	0.66	41
" Spanish	0.85	53
Maple	0.62–0.75	39–47
Oak	0.60–0.90	37–56
Pear-tree	0.61–0.73	38–45
Plum-tree	0.66–0.78	41–49
Poplar	0.35–0.5	22–31
Satinwood	0.95	59
Sycamore	0.40–0.60	24–37
Teak, Indian	0.66–0.88	41–55
" African	0.98	61
Walnut	0.64–0.70	40–43
Water gum	1.00	62
Willow	0.40–0.60	24–37

* Where the temperature is not given, ordinary atmospheric temperature is understood.

DENSITY OR MASS IN GRAMS PER CUBIC CENTIMETER AND POUNDS PER CUBIC FOOT OF VARIOUS SOLIDS.

N. B. The density of a specimen depends considerably on its state and previous treatment; especially is this the case with porous materials.

Material.	Grams per cu. cm.	Pounds per cu. foot.	Material.	Grams per cu. cm.	Pounds per cu. foot.
Agate	2.5–2.7	156–168	Gum arabic	1.3–1.4	80– 85
Alabaster:			Gypsum	2.31–2.33	144–145
Carbonate	2.69–2.78	168–173	Hematite	4.9–5.3	306–330
Sulphate	2.26–2.32	141–145	Hornblende	3.0	187
Albite	2.62–2.65	163–165	Ice	0.917	57.2
Amber	1.06–1.11	66– 69	Ilmenite	4.5–5.	280–310
Amphiboles	2.9–3.2	180–200	Ivory	1.83–1.92	114–120
Anorthite	2.74–2.76	171–172	Labradorite	2.7–2.72	168–170
Anthracite	1.4–1.8	87–112	Lava: basaltic	2.8–3.0	175–185
Asbestos	2.0–2.8	125–175	trachytic	2.0–2.7	125–168
Asphalt	1.1–1.5	69– 94	Leather: dry	0.86	54
Basalt	2.4–3.1	150–190	greased	1.02	64
Beeswax	0.96–0.97	60– 61	Lime: mortar	1.65–1.78	103–111
Beryl	2.69–2.7	168–168	slaked	1.3–1.4	81– 87
Biotite	2.7–3.1	170–190	Limestone	2.68–2.76	167–171
Bone	1.7–2.0	106–125	Litharge:		
Brick	1.4–2.2	87–137	Artificial	9.3–9.4	580–585
Butter	0.86–0.87	53– 54	Natural	7.8–8.0	490–500
Calamine	4.1–4.5	255–280	Magnetite	4.9–5.2	306–324
Caoutchouc	0.92–0.99	57– 62	Malachite	3.7–4.1	231–256
Celluloid	1.4	87	Marble	2.6–2.84	160–177
Cement, set	2.7–3.0	170–190	Meerschaum	0.99–1.28	62– 80
Chalk	1.9–2.8	118–175	Mica	2.6–3.2	165–200
Charcoal: oak	0.57	35	Muscovite	2.76–3.00	172–225
pine	0.28–0.44	18– 28	Ochre	3.5	218
Chrome yellow	6.00	374	Oligoclase	2.65–2.67	165–167
Chromite	4.32–4.57	270–285	Olivine	3.27–3.37	204–210
Cinnabar	8.12	507	Opal	2.2	137
Clay	1.8–2.6	122–162	Orthoclase	2.58–2.61	161–163
Coal, soft	1.2–1.5	75– 94	Paper	0.7–1.15	44– 72
Cocoa butter	0.89–0.91	56– 57	Paraffin	0.87–0.91	54– 57
Coke	1.0–1.7	62–105	Peat	0.84	52
Copal	1.04–1.14	65– 71	Pitch	1.07	67
Corundum	3.9–4.0	245–250	Porcelain	2.3–2.5	143–156
Diamond:			Porphyry	2.6–2.9	162–181
Anthracitic	1.66	104	Pyrite	4.95–5.1	309–318
Carbonado	3.01–3.25	188–203	Quartz	2.65	165
Diorite	2.52	157	Quartzite	2.73	170
Dolomite	2.84	177	Resin	1.07	67
Ebonite	1.15	72	Rock salt	2.18	136
Emery	4.0	250	Rutile	6.00–6.5	374–406
Epidote	3.25–3.5	203–218	Sandstone	2.14–2.36	134–147
Feldspar	2.55–2.75	159–172	Serpentine	2.50–2.65	156–165
Flint	2.63	164	Slag, furnace	2.0–3.9	125–240
Fluorite	3.18	198	Slate	2.6–3.3	162–205
Gamboge	1.2	75	Soapstone	2.6–2.8	162–175
Garnet	3.15–4.3	197–268	Starch	1.53	95
Gas carbon	1.88	117	Sugar	1.61	100
Gelatine	1.27	180	Talc	2.7–2.8	168–174
Glass: common	2.4–2.8	150–175	Tallow	0.91–0.97	57– 60
flint	2.9–5.9	180–370	Topaz	3.5–3.6	219–223
Glue	1.27	80	Tourmaline	3.0–3.2	190–200
Granite	2.64–2.76	165–172	Zircon	4.68–4.70	292–293
Graphite	2.30–2.72	144–170			

TABLE 63.

DENSITY OR MASS IN GRAMS PER CUBIC CENTIMETER AND POUNDS PER CUBIC FOOT OF VARIOUS ALLOYS (BRASSES AND BRONZES).

Alloy.	Grams per cubic centimeter.	Pounds per cubic foot.
Brasses: Yellow, 70Cu + 30Zn, cast	8.44	527
" " " rolled	8.56	534
" " " drawn	8.70	542
" Red, 90Cu + 10Zn	8.60	536
" White, 50Cu + 50Zn	8.20	511
Bronzes: 90Cu + 10Sn	8.78	548
" 85Cu + 15Sn	8.89	555
" 80Cu + 20Sn	8.74	545
" 75Cu + 25Sn	8.83	551
German Silver: Chinese, 26.3Cu + 36.6Zn + 36.8Ni	8.30	518
" " Berlin (1) 52Cu + 26Zn + 22Ni	8.45	527
" " " (2) 59Cu + 30Zn + 11Ni	8.34	520
" " " (3) 63Cu + 30Zn + 6Ni	8.30	518
" " Nickelin	8.77	547
Lead and Tin: 87.5Pb + 12.5Sn	10.60	661
" " " 84Pb + 16Sn	10.33	644
" " " 77.8Pb + 22.2Sn	10.05	627
" " " 63.7Pb + 36.3Sn	9.43	588
" " " 46.7Pb + 53.3Sn	8.73	545
" " " 30.5Pb + 69.5Sn	8.24	514
Bismuth, Lead, and Tin: 53Bi + 40Pb + 7Cd	10.56	659
Wood's Metal: 50Bi + 25Pb + 12.5Cd + 12.5Sn	9.70	605
Cadmium and Tin: 32Cd + 68Sn	7.70	480
Gold and Copper: 98Au + 2Cu	18.84	1176
" " " 96Au + 4Cu	18.36	1145
" " " 94Au + 6Cu	17.95	1120
" " " 92Au + 8Cu	17.52	1093
" " " 90Au + 10Cu	17.16	1071
" " " 88Au + 12Cu	16.81	1049
" " " 86Au + 14Cu	16.47	1027
Aluminum and Copper: 10Al + 90Cu	7.69	480
" " " 5Al + 95Cu	8.37	522
" " " 3Al + 97Cu	8.69	542
Aluminum and Zinc: 91Al + 9Zn	2.80	175
Platinum and Iridium: 90Pt + 10Ir	21.62	1348
" " " 85Pt + 15Ir	21.62	1348
" " " 66.67Pt + 33.33Ir	21.87	1364
" " " 5Pt + 95Ir	22.38	1396
Constantin: 60Cu + 40Ni	8.88	554
Magnalium: 70Al + 30Mg	2.0	125
Manganin: 84Cu + 12Mn + 4Ni	8.5	530
Platinoid: German silver + little Tungsten	9.0	560

TABLE 64.—DENSITIES OF VARIOUS NATURAL AND ARTIFICIAL MINERALS.

(See also Table 62.)

Name and Formula.	Density grams per cc.	Sp. Vol. cc. per gram.	Reference.
Pure compounds, all at 25°C			
Magnesia, MgO	3.603	.2775	1
Lime, CaO	3.306	.3025	2
Forms of SiO_2:			
Quartz, natural	2.646	.3779	"
" artificial	2.642	.3785	"
Cristobalite, artificial	2.319	.4312	"
Silica glass	2.206	.4533	"
Forms of Al_2SiO_5:			
Sillimanite glass	2.53	.395	3
Sillimanite cryst.	3.022	.3309	"
Forms of $MgSiO_3$:			
β Monoclinic pyroxene	3.183	.3142	5
α' Orthorhombic pyroxene	3.166	.3159	"
β' Monoclinic amphibole			"
γ' Orthorhombic amphibole	2.849	.3510	"
Glass	2.735	.3656	"
Forms of $CaSiO_3$:			
α (Pseudo-wollastonite)	2.904	.3444	2
β (Wollastonite)	2.906	.3441	"
Glass	2.895	.3454	"
Forms of Ca_2SiO_4:			
α — calcium-orthosilicate	3.26	.307	"
β — " "	3.27	.306	"
γ — " "	2.965	.337	"
β' — " "			
Lime-alumina compounds:			
$3CaO \cdot Al_2O_3$	3.029	.3301	3
$5CaO \cdot 3Al_2O_3$	2.820	.3546	"
$CaO \cdot Al_2O_3$	2.972	.3365	"
$3CaO \cdot 5Al_2O_3$			
$3CaO \cdot 5Al_2O_3$, unstable form	3.04	.329	"
Forms of $MgSiO_3 \cdot CaSiO_3$:			
Diopside, natural, cryst.	3.258	.3069	4
" artificial, "	3.265	.3063	"
" glass	2.846	.3514	1

Name and Formula.	Density grams per cc.	Sp. Vol. cc. per gram.	Reference.
Feldspars:			
Albite glass, $NaAlSi_3O_8$, art.	2.375	.4210	6
Albite cryst., $NaAlSi_3O_8$, art.	2.597	.3851	"
Anorthite glass, $CaAl_2Si_2O_8$, art.	2.692	.3715	"
Anorthite cryst., $CaAl_2Si_2O_8$, art.	2.757	.3627	"
Soda anorthite, $NaAlSiO_4$, art.	2.563	.3902	7
Borax, glass, $Na_2B_4O_7$	2.36	.423	6
" cryst. "	2.27	.440	"
Fluorite, natural, CaF_2 (20°)	3.180	.3145	8
$(NH_4)_2SO_4$ (30°)	1.765	.5666	9
K_2SO_4 (30°)	2.657	.3764	"
KCl, fine powder (30°)	1.984	.5040	"
Forms of ZnS:			
Sphalerite, natural*	4.090	.2444	10
Wurtzite, artificial†	4.087	.2447	"
Greenockite, artificial	4.820	.2075	"
Forms of HgS:			
Cinnabar, artificial	8.176	.1223	"
Metacinnabar, artificial	7.58	.132	"
Minerals:			
Gehlenite, from Velardena	3.03	.330	11
Spurrite, from Velardena, $2Ca_2SiO_4 \cdot CaCO_3$	3.005	.3328	"
Hillebrandite, from Velardena, $CaSiO_3 \cdot Ca(OH)_2$	2.684	.3726	"
Pyrite, natural, FeS_2	5.012	.1995	10
Marcasite, natural, FeS_2	4.873	.2052	"

* Only 0.15% Fe total impurity.
† Same composition as Sphalerite.

References: 1, Larsen 1909; 2, Day and Shepherd; 3, Shepherd and Rankin, 1909; 4, Allen and White, 1909; 5, Allen, Wright and Clement, 1906; 6, Day and Allen, 1905; 7, Washington and Wright, 1910; 8, Merwin, 1911; 9, Johnston and Adams, 1911; 10, Allen and Crenshaw, 1912; 11, Wright, 1908.

All the data of this table are from the Geophysical Laboratory, Washington.

TABLE 65.—DENSITIES OF MOLTEN TIN AND TIN-LEAD EUTECTIC.

Temperature	250°C.	300°	400°	500°	600°	900°	1200°	1400°	1600°
Molten tin	6.982	6.943	6.875	6.814	6.755	6.578	6.399	6.280	6.162
37 pts. Pb, 63, Sn.*	8.011	7.965	7.879	7.800	7.731	–	–	–	–

* Melts at 181. Day and Sosman, Geophysical Laboratory, unpublished.

For further densities inorganic substances see table 238.
" " " organic " " " 244.

WEIGHT OF SHEET METAL.

TABLE 66.—Weight of Sheet Metal. (Metric Measure.)

This table gives the weight in grams of a plate one meter square and of the thickness stated in the first column.

Thickness in thousandths of a cm.	Iron.	Copper.	Brass.	Aluminum.	Platinum.	Gold.	Silver.
1	78.0	89.0	85.6	26.7	215.0	193.0	105.0
2	156.0	178.0	171.2	53.4	430.0	386.0	210.0
3	234.0	267.0	256.8	80.1	645.0	579.0	315.0
4	312.0	356.0	342.4	106.8	860.0	772.0	420.0
5	390.0	445.0	428.0	133.5	1075.0	965.0	525.0
6	468.0	534.0	513.6	160.2	1290.0	1158.0	630.0
7	546.0	623.0	599.2	186.9	1505.0	1351.0	735.0
8	624.0	712.0	684.8	213.6	1720.0	1544.0	840.0
9	702.0	801.0	770.4	240.3	1935.0	1737.0	945.0
10	780.0	890.0	856.0	267.0	2150.0	1930.0	1050.0

TABLE 67.—Weight of Sheet Metal. (British Measure.)

Thickness in Mils.	Iron.	Copper.	Brass.	Aluminum.		Platinum.	
	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Pounds per Sq. Foot.	Ounces per Sq. Foot.	Pounds per Sq. Foot.	Ounces per Sq. Foot.
1	.04058	.04630	.04454	.01389	.2222	.1119	1.790
2	.08116	.09260	.08908	.02778	.4445	.2237	3.579
3	.12173	.13890	.13363	.04167	.6667	.3356	5.369
4	.16231	.18520	.17817	.05556	.8890	.4474	7.158
5	.20289	.23150	.22271	.06945	1.1112	.5593	8.948
6	.24347	.27780	.26725	.08334	1.3335	.6711	10.738
7	.28405	.32411	.31179	.09723	1.5557	.7830	12.527
8	.32463	.37041	.35634	.11112	1.7780	.8948	14.317
9	.36520	.41671	.40088	.12501	2.0002	1.0067	16.106
10	.40578	.46301	.44542	.13890	2.2224	1.1185	17.896

Thickness in Mils.	Gold.		Silver.	
	Troy Ounces per Sq. Foot.	Grains per Sq. Foot.	Troy Ounces per Sq. Foot.	Grains per Sq. Foot.
1	1.4642	702.8	0.7967	382.4
2	2.9285	1405.7	1.5933	764.8
3	4.3927	2108.5	2.3900	1147.2
4	5.8570	2811.3	3.1867	1529.6
5	7.3212	3514.2	3.9833	1912.0
6	8.7854	4217.0	4.7800	2294.4
7	10.2497	4919.8	5.5767	2676.8
8	11.7139	5622.7	6.3734	3059.2
9	13.1782	6325.5	7.1700	3441.6
10	14.6424	7028.3	7.9667	3824.0

TABLE 68.

DENSITY OF LIQUIDS.

Density or mass in grams per cubic centimeter and in pounds per cubic foot of various liquids.

Liquid.	Grams per cubic centimeter.	Pounds per cubic foot.	Temp. C.
Acetone	0.792	49.4	20°
Alcohol, ethyl	0.807	50.4	0
" methyl	0.810	50.5	0
Anilin	1.035	64.5	0
Benzol	0.899	56.1	0
Bromine	3.187	199.0	0
Carbolic acid (crude)	0.950–0.965	59.2–60.2	15
Carbon disulphide	1.293	80.6	0
Chloroform	1.480	92.3	18
Ether	0.736	45.9	0
Gasoline	0.66–0.69	41.0–43.0	–
Glycerine	1.260	78.6	0
Milk	1.028–1.035	64.2–64.6	–
Naphtha (wood)	0.848–0.810	52.9–50.5	0
Naphtha (petroleum ether)	0.665	41.5	15
Oils: Amber	0.800	49.9	15
Anise-seed	0.996	62.1	16
Camphor	0.910	56.8	–
Castor	0.969	60.5	15
Cocoanut	0.925	57.7	15
Cotton Seed	0.926	57.8	16
Creosote	1.040–1.100	64.9–68.6	15
Lard	0.920	57.4	15
Lavender	0.877	54.7	16
Lemon	0.844	52.7	16
Linseed (boiled)	0.942	58.8	15
Olive	0.918	57.3	15
Palm	0.905	56.5	15
Pine	0.850–0.860	53.0–54.0	15
Poppy	0.924	57.7	–
Rapeseed (crude)	0.915	57.1	15
" (refined)	0.913	57.0	15
Resin	0.955	59.6	15
Train *or* Whale	0.918–0.925	57.3–57.7	15
Turpentine	0.873	54.2	16
Valerian	0.965	60.2	16
Petroleum	0.878	54.8	0
" (light)	0.795–0.805	49.6–50.2	15
Pyroligneous acid	0.800	49.9	0
Water	1.000	62.4	4

TABLE 69.

DENSITY OF GASES.

The following table gives the density of the gases at 0° C, 76 cm. pressure, at sea-level and latitude 45° relative to air as unity and under the same conditions; also the weight of one liter in grams and one cubic foot in pounds.

Gas.	Specific Gravity.	Grams per liter.	Pounds per cubic foot.	Reference.
Air	1.000	1.2928	.08071	Rayleigh; Leduc.
Acetylene	0.92	1.1620	.07254	Berthelot, 1860.
Ammonia	0.597	0.7706	.04811	Leduc, C. R. 125, 1897.
Argon	1.379	1.782	.1112	Ramsey-Travers, Proc. R. Soc. 67, 1900.
Bromine	5.524	7.1388	.4457	Jahn, 1882.
Butane	2.01	2.594	.16194	Frankland, Ann. Ch. Pharm. 71.
Carbon dioxide	1.5291	1.9768	.12341	Guye, Pintza, 1908.
" monoxide	0.9672	1.2506	.07807	Rayleigh, Proc. R. Soc. 62, 1897.
Chlorine	2.491	3.1674	.19774	Leduc, C. R. 125, 1897.
Coal gas { from	0.320	0.414	.02583	
Coal gas { to	0.740	0.957	.05973	
Cyanogen	1.806	2.3229	.14522	Gay-Lussac.
Ethane	1.0494	1.3567	.08470	Baume, Perot, J. Ch. et Phys. 1908.
Fluorine	1.26	1.697	.1059	Moissan, C. R. 109.
Helium	1.368	0.1787	.01116	Ramsay-Travers, Proc. R. Soc. 67, 1900.
Hydrofluoric acid	0.7126	0.894	.05581	Thorpe-Hambley, J. Chem. Soc. 53.
Hydrobromic acid	2.71	3.6163	.2258	Löwig, Gmelin-Kraut, Org. Chem.
Hydrochloric acid	1.2684	1.6398	.10237	Guye-Gazarian, 1908.
Hydrogen	0.0696	0.09004	.005621	Rayleigh, Proc. R. Soc. 53, 1893.
Hydrogen sulphide	1.1895	1.5230	.09508	Leduc, C. R. 125, 1897.
Krypton	2.868	3.708	.2315	Watson, J. Ch. Soc. 1910.
Methane	0.5576	0.7160	.04470	Thomson.
Neon	0.6963	0.9002	.0558	Watson, J. Ch. Soc. 1910.
Nitrogen	0.9673	1.2514	.07812	Rayleigh, Proc. R. Soc. 62, 1897.
Nitric oxide, NO	1.0367	1.3402	.08367	Guye, Davila, 1908.
Nitrous oxide, N_2O	1.5298	1.9777	.12347	Guye, Pintza, 1908.
Oxygen	1.053	1.4292	.08922	Rayleigh, Proc. R. Soc. 62, 1897.
Sulphur dioxide	2.2639	2.9266	.18271	Jaquerod, Pintza, 1908.
Steam at 100°	0.469	0.581	.0363	
Xenon	4.526	5.851	.3653	Watson, J. Ch. Soc. 1910.

Compiled partly from Landolt-Börnstein-Meyerhoffer's Physikalisch-Chemische Tabellen.

TABLE 70.

DENSITY OF AQUEOUS SOLUTIONS.*

The following table gives the density of solutions of various salts in water. The numbers give the weight in grams per cubic centimeter. For brevity the substance is indicated by formula only.

Substance.	Weight of the dissolved substance in 100 parts by weight of the solution.									Temp. C.	Authority.
	5	10	15	20	25	30	40	50	60		
K_2O	1.047	1.098	1.153	1.214	1.284	1.354	1.503	1.659	1.809	15.	Schiff.
KOH	1.040	1.082	1.027	1.076	1.229	1.286	1.410	1.538	1.666	15.	"
Na_2O	1.073	1.144	1.218	1.284	1.354	1.421	1.557	1.689	1.829	15.	"
$NaOH$	1.058	1.114	1.169	1.224	1.279	1.331	1.436	1.539	1.642	15.	"
NH_3	0.978	0.959	0.940	0.924	0.909	0.896	–	–	–	16.	Carius.
NH_4Cl	1.015	1.030	1.044	1.058	1.072	–	–	–	–	15.	Gerlach.
KCl	1.031	1.065	1.099	1.135	–	–	–	–	–	15.	"
$NaCl$	1.035	1.072	1.110	1.150	1.191	–	–	–	–	15.	"
$LiCl$	1.029	1.057	1.085	1.116	1.147	1.181	1.255	–	–	15.	"
$CaCl_2$	1.041	1.086	1.132	1.181	1.232	1.286	1.402	–	–	15.	"
$CaCl_2 + 6H_2O$	1.019	1.040	1.061	1.083	1.105	1.128	1.176	1.225	1.276	18.	Schiff.
$AlCl_3$	1.030	1.072	1.111	1.153	1.196	1.241	1.340	–	–	15.	Gerlach.
$MgCl_2$	1.041	1.085	1.130	1.177	1.226	1.278	–	–	–	15.	"
$MgCl_2+6H_2O$	1.014	1.032	1.049	1.067	1.085	1.103	1.141	1.183	1.222	24.	Schiff.
$ZnCl_2$	1.043	1.089	1.135	1.184	1.236	1.289	1.417	1.563	1.737	19.5	Kremers.
$CdCl_2$	1.043	1.087	1.138	1.193	1.254	1.319	1.469	1.653	1.887	19.5	"
$SrCl_2$	1.044	1.092	1.143	1.198	1.257	1.321	–	–	–	15.	Gerlach.
$SrCl_2 + 6H_2O$	1.027	1.053	1.082	1.111	1.042	1.174	1.242	1.317	–	15.	"
$BaCl_2$	1.045	1.094	1.147	1.205	1.269	–	–	–	–	15.	"
$BaCl_2 + 2H_2O$	1.035	1.075	1.119	1.166	1.217	1.273	–	–	–	21.	Schiff.
$CuCl_2$	1.044	1.091	1.155	1.221	1.291	1.360	1.527	–	–	17.5	Franz.
$NiCl_2$	1.048	1.098	1.157	1.223	1.299	–	–	–	–	17.5	"
$HgCl_2$	1.041	1.092	–	–	–	–	–	–	–	20.	Mendelejeff.
Fe_2Cl_6	1.041	1.086	1.130	1.179	1.232	1.290	1.413	1.545	1.668	17.5	Hager.
$PtCl_4$	1.046	1.097	1.153	1.214	1.285	1.362	1.546	1.785	–	–	Precht.
$SnCl_2 + 2H_2O$	1.032	1.067	1.104	1.143	1.185	1.229	1.329	1.444	1.580	15.	Gerlach.
$SnCl_4 + 5H_2O$	1.029	1.058	1.089	1.122	1.157	1.193	1.274	1.365	1.467	15.	"
$LiBr$	1.033	1.070	1.111	1.154	1.202	1.252	1.366	1.498	–	19.5	Kremers.
KBr	1.035	1.073	1.114	1.157	1.205	1.254	1.364	–	–	19.5	"
$NaBr$	1.038	1.078	1.123	1.172	1.224	1.279	1.408	1.563	–	19.5	"
$MgBr_2$	1.041	1.085	1.135	1.189	1.245	1.308	1.449	1.623	–	19.5	"
$ZnBr_2$	1.043	1.091	1.144	1.202	1.263	1.328	1.473	1.648	1.873	19.5	"
$CdBr_2$	1.041	1.088	1.139	1.197	1.258	1.324	1.479	1.678	–	19.5	"
$CaBr_2$	1.042	1.087	1.137	1.192	2.250	1.313	1.459	1.639	–	19.5	"
$BaBr_2$	1.043	1.090	1.142	1.199	1.260	1.327	1.483	1.683	–	19.5	"
$SrBr_2$	1.043	1.089	1.140	1.198	1.260	1.328	1.489	1.693	1.953	19.5	"
KI	1.036	1.076	1.118	1.164	1.216	1.269	1.394	1.544	1.732	19.5	"
LiI	1.036	1.077	1.122	1.170	1.222	1.278	1.412	1.573	1.775	19.5	"
NaI	1.038	1.080	1.126	1.177	1.232	1.292	1.430	1.598	1.808	19.5	"
ZnI_2	1.043	1.089	1.138	1.194	1.253	1.316	1.467	1.648	1.873	19.5	"
CdI_2	1.042	1.086	1.136	1.192	1.251	1.317	1.474	1.678	–	19.5	"
MgI_2	1.041	1.086	1.137	1.192	1.252	1.318	1.472	1.666	1.913	19.5	"
CaI_2	1.042	1.088	1.138	1.196	1.258	1.319	1.475	1.663	1.908	19.5	"
SrI_2	1.043	1.089	1.140	1.198	1.260	1.328	1.489	1.693	1.953	19.5	"
BaI_2	1.043	1.089	1.141	1.199	1.263	1.331	1.493	1.702	1.968	19.5	"
$NaClO_3$	1.035	1.068	1.106	1.145	1.188	1.233	1.329	–	–	19.5	"
$NaBrO_3$	1.039	1.081	1.127	1.176	1.229	1.287	–	–	–	19.5	"
KNO_3	1.031	1.064	1.099	1.135	–	–	–	–	–	15.	Gerlach.
$NaNO_3$	1.031	1.065	1.101	1.140	1.180	1.222	1.313	1.416	–	20.2	Schiff.
$AgNO_3$	1.044	1.090	1.140	1.195	1.255	1.322	1.479	1.675	1.918	15.	Kohlrausch.

* Compiled from two papers on the subject by Gerlach in the "Zeit. für Anal. Chim.," vols. 8 and 27.

DENSITY OF AQUEOUS SOLUTIONS.

Substance.	Weight of the dissolved substance in 100 parts by weight of the solution.									Temp. C.	Authority.
	5	10	15	20	25	30	40	50	60		
NH_4NO_3	1.020	1.041	1.063	1.085	1.107	1.131	1.178	1.229	1.282	17.5	Gerlach.
$Zn(NO_3)_2$	1.048	1.095	1.146	1.201	1.263	1.325	1.456	1.597	–	17.5	Franz.
$Zn(NO_3)_2+6H_2O$	·	1.054	–	1.113		1.178	1.250	1.329	–	14.	Oudemans.
$Ca(NO_3)_2$	1.037	1.075	1.118	1.162	1.211	1.260	1.367	1.482	1.604	17.5	Gerlach.
$Cu(NO_3)_2$	1.044	1.093	1.143	1.203	1.263	1.328	1.471	–	–	17.5	Franz.
$Sr(NO_3)_2$	1.039	1.083	1.129	1.179	–	–	–	–	–	19.5	Kremers.
$Pb(NO_3)_2$	1.043	1.091	1.143	1.199	1.262	1.332	–	–	–	17.5	Gerlach.
$Cd(NO_3)_2$	1.052	1.097	1.150	1.212	1.283	1.355	1.536	1.759	–	17.5	Franz.
$Co(NO_3)_2$	1.045	1.090	1.137	1.192	1.252	1.318	1.465	–	–	17.5	"
$Ni(NO_3)_2$	1.045	1.090	1.137	1.192	1.252	1.318	1.465	–	–	17.5	"
$Fe_2(NO_3)_6$	1.039	1.076	1.117	1.160	1.210	1.261	1.373	1.496	1.657	17.5	"
$Mg(NO_3)_2+6H_2O$	1.018	1.038	1.060	1.082	1.105	1.129	1.179	1.232	–	21	Schiff.
$Mn(NO_3)_2+6H_2O$	1.025	1.052	1.079	1.108	1.138	1.169	1.235	1.307	1.386	8	Oudemans.
K_2CO_3	1.044	1.092	1.141	1.192	1.245	1.300	1.417	1.543	–	15	Gerlach.
$K_2CO_3 + 2H_2O$	1.037	1.072	1.110	1.150	1.191	1.233	1.320	1.415	1.511	15.	"
$Na_2CO_3 10H_2O$	1.019	1.038	1.057	1.077	1.098	1.118	–	–		15.	"
$(NH_4)_2SO_4$	1.027	1.055	1.084	1.113	1.142	1.170	1.226	1.287	–	19.	Schiff.
$Fe_2(SO_4)_3$	1.045	1.096	1.150	1.207	1.270	1.336	1.489	–	–	18.	Hager.
$FeSO_4 + 7H_2O$	1.025	1.053	1.081	1.111	1.141	1.173	1.238	–	–	17.2	Schiff.
$MgSO_4$	1.051	1.104	1.161	1.221	1.284	–	–	–		15	Gerlach.
$MgSO + 7H_2O$	1.025	1.050	1.075	1.101	1.129	1.155	1.215	1.278	–	15.	"
$Na_2So_4 + 10H_2O$	1.019	1.039	1.059	1.081	1.102	1.124	–	–		15.	"
$CuSO_4 + 5H_2O$	1.031	1.064	1.098	1.134	1.173	1.213	–	–		18.	Schiff.
$MnSO_4 + 4H_2O$	1.031	1.064	1.099	1.135	1.174	1.214	1.303	1.398		15.	Gerlach.
$ZnSO_4 + 7H_2O$	1.027	1.057	1.089	1.122	1.156	1.191	1.269	1.351	1.443	20.5	Schiff.
$Fe_2(SO)_3+K_2SO_4 +24H_2O$	1.026	1.045	1.066	1.088	1.112	1.141	–	–	–	17.5	Franz.
$Cr_2(SO)_3+K_2SO_4 + 24H_2O$	1.016	1.033	1.051	1.073	1.099	1.126	1.188	1.287	1.454	17.5	"
$MgSO_4 + K_2SO_4 + 6H_2O$	1.032	1.066	1.101	1.138	–	–	–	–	–	15.	Schiff.
$(NH_4)_2SO_4 + FeSO_4 + 6H_2O$	1.028	1.058	1.090	1.122	1.154	1.191	–	–	–	19.	"
K_2CrO_4	1.039	1.082	1.127	1.174	1.225	1.279	1.397	–	–	19.5	"
$K_2Cr_2O_7$	1.035	1.071	1.108	–	–	–	–	–	–	19.5	Kremers.
$Fe(Cy)_6K_4$	1.028	1.059	1.092	1.126	–	–	–	–	–	15.	Schiff.
$Fe(Cy)_6K_3$	1.025	1.053	1.070	1.113	–	–	–	–	–	13	"
$Pb(C_2H_3O_2)_2 + 3H_2O$	1.031	1.064	1.100	1.137	1.177	1.220	1.315	1.426	–	15.	Gerlach.
$2NaOH + As_2O_5 + 24H_2O$	1.020	1.042	1.066	1.089	1.114	1.140	1.194	–	–	14.	Schiff.
	5	10	15	20	30	40	60	80	100		
SO_3	1.040	1.084	1.132	1.179	1.277	1.389	1.564	1.840	–	15.	Brineau.
SO_2	1.013	1.028	1.045	1.063	–	–	–	–	–	4.	Schiff.
N_2O_5	1.033	1.069	1.104	1.141	1.217	1.294	1.422	1.506	–	15.	Kolb.
$C_4H_6O_6$	1.021	1.047	1.070	1.096	1.150	1.207	–	–	–	15.	Gerlach.
$C_6H_8O_7$	1.018	1.038	1.058	1.079	1.123	1.170	1.273	–	–	15.	"
Cane sugar	1.019	1.039	1.060	1.082	1.129	1.178	1.289	–	–	17.5	"
HCl	1.025	1.050	1.075	1.101	1.151	1.200	–	–	–	15.	Kolb.
HBr	1.035	1.073	1.114	1.158	1.257	1.376	–	–	–	14.	Topsöe.
HI	1.037	1.077	1.118	1.165	1.271	1.400	–	–	–	13.	"
H_2SO_4	1.032	1.069	1.106	1.145	1.223	1.307	1.501	1.732	1.838	15.	Kolb.
H_2SiFl_6	1.040	1.082	1.127	1.174	1.273	–	–	–	–	17.5	Stolba.
P_2O_5	1.035	1.077	1.119	1.167	1.271	1.385	1.676	–	–	17.5	Hager.
$P_2O_5 + 3H_2O$	1.027	1.057	1.086	1.119	1.188	1.264	1.438	–	–	15.	Schiff.
HNO	1.028	1.056	1.088	1.119	1.184	1.250	1.373	1.459	1.528	15.	Kolb.
$C_2H_4O_2$	1.007	1.014	1.021	1.028	1.041	1.052	1.068	1.075	1.055	15.	Oudemans.

TABLE 71.

DENSITY OF PURE WATER FREE FROM AIR.

[Under standard pressure (76 cm), at every tenth part of a degree of the international hydrogen scale from 0° to 41° C, in grams per milliliter [1]]

Degrees Centigrade.	Tenths of Degrees. 0	1	2	3	4	5	6	7	8	9	Mean Differences.
0	0.999 8681	8747	8812	8875	8936	8996	9053	9109	9163	9216	+ 59
1	9267	9315	9363	9408	9452	9494	9534	9573	9610	9645	+ 41
2	9679	9711	9741	9769	9796	9821	9844	9866	9887	9905	+ 24
3	9922	9937	9951	9962	9973	9981	9988	9994	9998	*0000	+ 8
4	1.000 0000	*9999	*9996	*9992	*9986	*9979	*9970	*9960	*9947	*9934	− 8
5	0.999 9919	9902	9884	9864	9842	9819	9795	9769	9742	9713	− 24
6	9682	9650	9617	9582	9545	9507	9468	9427	9385	9341	− 39
7	9296	9249	9201	9151	9100	9048	8994	8938	8881	8823	− 53
8	8764	8703	8641	8577	8512	8445	8377	8308	8237	8165	− 67
9	8091	8017	7940	7863	7784	7704	7622	7539	7455	7369	− 81
10	7282	7194	7105	7014	6921	6826	6729	6632	6533	6432	− 95
11	6331	6228	6124	6020	5913	5805	5696	5586	5474	5362	−108
12	5248	5132	5016	4898	4780	4660	4538	4415	4291	4166	−121
13	4040	3912	3784	3654	3523	3391	3257	3122	2986	2850	−133
14	2712	2572	2431	2289	2147	2003	1858	1711	1564	1416	−145
15	1266	1114	0962	0809	0655	0499	0343	0185	0026	*9865	−156
16	0.998 9705	9542	9378	9214	9048	8881	8713	8544	8373	8202	−168
17	8029	7856	7681	7505	7328	7150	6971	6791	6610	6427	−178
18	6244	6058	5873	5686	5498	5309	5119	4927	4735	4541	−190
19	4347	4152	3955	3757	3558	3358	3158	2955	2752	2549	−200
20	2343	2137	1930	1722	1511	1301	1090	0878	0663	0449	−211
21	0233	0016	*9799	*9580	*9359	*9139	*8917	*8694	*8470	*8245	−221
22	0.997 8019	7792	7564	7335	7104	6873	6641	6408	6173	5938	−232
23	5702	5466	5227	4988	4747	4506	4264	4021	3777	3531	−242
24	3286	3039	2790	2541	2291	2040	1788	1535	1280	1026	−252
25	0770	0513	0255	*9997	*9736	*9476	*9214	*8951	*8688	*8423	−261
26	0.996 8158	7892	7624	7356	7087	6817	6545	6273	6000	5726	−271
27	5451	5176	4898	4620	4342	4062	3782	3500	3218	2935	−280
28	2652	2366	2080	1793	1505	1217	0928	0637	0346	0053	−289
29	0.995 9761	9466	9171	8876	8579	8282	7983	7684	7383	7083	−298
30	6780	6478	6174	5869	5564	5258	4950	4642	4334	4024	−307
31	3714	3401	3089	2776	2462	2147	1832	1515	1198	0880	−315
32	0561	0241	*9920	*9599	*9276	*8954	*8630	*8304	*7979	*7653	−324
33	0.994 7325	6997	6668	6338	6007	5676	5345	5011	4678	4343	−332
34	4007	3671	3335	2997	2659	2318	1978	1638	1296	0953	−340
35	0610	0267	*9922	*9576	*9230	*8883	*8534	*8186	*7837	*7486	−347
36	0.993 7136	6784	6432	6078	5725	5369	5014	4658	4301	3943	−355
37	3585	3226	2866	2505	2144	1782	1419	1055	0691	0326	−362
38	0.992 9960	9593	9227	8859	8490	8120	7751	7380	7008	6636	−370
39	6263	5890	5516	5140	4765	4389	4011	3634	3255	2876	−377
40	2497	2116	1734	1352	0971	0587	0203	*9818	*9433	*9047	−384
41	0.991 8661										

[1] According to P. Chappuis, Bureau international des Poids et Mesures, Travaux et Mémoires, 13; 1907.

VOLUME IN CUBIC CENTIMETERS AT VARIOUS TEMPERATURES OF A CUBIC CENTIMETER OF WATER FREE FROM AIR AT THE TEMPERATURE OF MAXIMUM DENSITY.

Hydrogen Thermometer Scale.

Temp. C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.000132	125	118	112	106	100	095	089	084	079
1	073	069	064	059	055	051	047	043	039	035
2	032	029	026	023	020	018	016	013	011	009
3	008	006	005	004	003	002	001	001	000	000
4	000	000	000	001	001	002	003	004	005	007
5	008	010	012	014	016	018	021	023	026	029
6	032	035	039	042	046	050	054	058	062	066
7	070	075	080	085	090	095	101	106	112	118
8	124	130	137	142	149	156	162	169	176	184
9	191	198	206	214	222	230	238	246	254	263
10	272	281	290	299	308	317	327	337	347	357
11	367	377	388	398	409	420	430	441	453	464
12	476	487	499	511	522	534	547	559	571	584
13	596	609	623	636	649	661	675	688	702	715
14	729	743	757	772	786	800	815	830	844	859
15	873	890	905	920	935	951	967	983	998	015*
16	1.001031	047	063	080	097	113	130	147	164	182
17	198	216	233	252	269	287	305	323	341	358
18	378	396	415	433	452	471	490	510	529	548
19	568	588	606	626	646	667	687	707	728	748
20	769	790	811	832	853	874	895	916	938	960
21	981	002*	024*	046*	068*	091*	113*	135*	158*	181*
22	1.002203	226	249	271	295	319	342	364	389	412
23	436	459	483	507	532	556	581	605	629	654
24	679	704	729	754	779	804	829	854	879	905
25	932	958	983	010*	036*	061*	088*	115*	141*	168*
26	1.003195	221	248	275	302	330	357	384	412	439
27	467	495	523	550	579	607	635	663	692	720
28	749	776	806	836	865	893	922	951	981	011*
29	1.004041	069	100	129	160	189	220	250	280	310
30	341	371	403	432	464	494	526	557	588	619
31	651	682	713	744	777	808	840	872	904	936
32	968	001*	033*	066*	098*	132*	163*	197*	229*	263*
33	1.005296	328	361	395	427	461	496	530	562	597
34	631	665	698	732	768	802	836	871	904	940
35	975	009*	044*	078*	115*	150*	185*	219*	255*	290*

Reciprocals of the preceding table.

TABLE 73.

DENSITY AND VOLUME OF WATER.

The mass of one cubic centimeter at 4° C. is taken as unity.

Temp. C.	Density.	Volume.	Temp. C.	Density.	Volume.
−10°	0.99815	1.00186	+35°	0.99406	1.00598
−9	843	157	36	371	633
−8	869	131	37	336	669
−7	892	108	38	300	706
−6	912	088	39	263	743
−5	0.99930	1.00070	40	0.99225	1.00782
−4	945	055	41	187	821
−3	958	042	42	147	861
−2	970	031	43	107	901
−1	979	021	44	066	943
+0	0.99987	1.00013	45	0.99025	1.00985
1	993	007	46	0.98982	1.01028
2	997	003	47	940	072
3	999	001	48	896	116
4	1.00000	1.00000	49	852	162
5	0.99999	1.00001	50	0.98807	1.01207
6	997	003	51	762	254
7	993	007	52	715	301
8	988	012	53	669	349
9	981	019	54	621	398
10	0.99973	1.00027	55	0.98573	1.01448
11	963	037	60	324	705
12	952	048	65	059	979
13	940	060	70	0.97781	1.02270
14	927	073	75	489	576
15	0.99913	1.00087	80	0.97183	1.02899
16	897	103	85	0.96865	1.03237
17	880	120	90	534	590
18	862	138	95	192	959
19	843	157	100	0.95838	1.04343
20	0.99823	1.00177	110	0.9510	1.0515
21	802	198	120	.9434	1.0601
22	780	220	130	.9352	1.0693
23	757	244	140	.9264	1.0794
24	733	268	150	.9173	1.0902
25	0.99708	1.00293	160	0.9075	1.1019
26	682	320	170	.8973	1.1145
27	655	347	180	.8866	1.1279
28	627	375	190	.8750	1.1429
29	598	404	200	.8628	1.1590
30	0.99568	1.00434	210	0.850	1.177
31	537	465	220	.837	1.195
32	506	497	230	.823	1.215
33	473	530	240	.809	1.236
34	440	563	250	.794	1.259

* From — 10° to 0° the values are due to means from Pierre, Weidner, and Rosetti; from 0° to 41°, to Chappuis, 42° to 100°, to Thiesen; 110° to 250°, to means from the works of Ramsey, Young, Waterston, and Hirn.

Table 74.

DENSITY OF MERCURY.

Density or mass in grams per cubic centimeter, and the volume in cubic centimeters of one gram of mercury.

Temp. C.	Mass in grams per cu. cm.	Volume of 1 gram in cu. cms.	Temp. C.	Mass in grams per cu. cm.	Volume of 1 gram in cu. cms.
—10°	13.6202	0.0734205	30°	13.5217	0.0739552
—9	6177	4338	31	5193	9685
—8	6152	4472	32	5168	9819
—7	6128	4606	33	5144	9953
—6	6103	4739	34	5119	40087
—5	13.6078	0.0734873	35	13.5095	0.0740221
—4	6053	5006	36	5070	0354
—3	6029	5140	37	5046	0488
—2	6004	5273	38	5021	0622
—1	5979	5407	39	4997	0756
0	13.5955	0.0735540	40	13.4973	0.0740890
1	5930	5674	50	4729	2230
2	5905	5808	60	4486	3572
3	5880	5941	70	4243	4916
4	5856	6075	80	4001	6262
5	13.5831	0.0736208	90	13.3776	0.0747611
6	5807	6342	100	3518	8961
7	5782	6476	110	3283	50285
8	5757	6609	120	3044	1633
9	5733	6743	130	2805	2982
10	13.5708	0.0736877	140	13.2567	0.0754334
11	5683	7010	150	2330	5688
12	5659	7144	160	2093	7044
13	5634	7278	170	1856	8402
14	5610	7411	180	1620	9764
15	13.5585	0.0737545	190	13.1384	0.0761128
16	5560	7679	200	1148	2495
17	5536	7812	210	0913	3865
18	5511	7946	220	0678	5239
19	5487	8080	230	0443	6616
20	13.5462	0.0738213	240	13.0209	0.0767996
21	5438	8347	250	12.9975	9381
22	5413	8481	260	9741	70769
23	5389	8615	270	9507	2161
24	5364	8748	280	9273	3558
25	13.5340	0.0738882	290	12.9039	0.0774958
26	5315	9016	300	8806	6364
27	5291	9150	310	8572	7774
28	5266	9284	320	8339	9189
29	5242	9417	330	8105	80609
30	13.5217	0.0739551	340	12.7872	0.0782033
			350	7638	3464
			360	7405	4900

Thiesen und Scheel, Tätigkeither. Phys.-Techn. Reichsanstalt, 1897–1898; Chappuis, Trav. Bur. Int. 13, 1903.
Thiesen, Scheel, Sell; Wiss. Abh. Phys.-Techn. Reichsanstalt 2, p. 184, 1895.

TABLE 75.

DENSITIES OF MIXTURES OF ETHYL ALCOHOL AND WATER IN GRAMS PER MILLILITER.

The densities in this table are numerically the same as specific gravities at the various temperatures in terms of water at 4° C. as unity. Based upon work done at U. S. Bureau of Standards. See Bulletin Bur. Stds. vol. 9, no. 3; contains extensive bibliography; also Circular 19, 1913.

Per cent C_2H_5OH by weight	Temperatures.						
	10° C.	15° C.	20° C.	25° C.	30° C.	35° C.	40° C.
0	0.99973	0.99913	0.99823	0.99708	0.99568	0.99406	0.99225
1	785	725	636	520	379	217	034
2	602	542	453	336	194	031	.98846
3	426	365	275	157	014	.98849	663
4	258	195	103	.98984	.98839	672	485
5	098	032	.98938	817	670	501	311
6	.98946	.98877	780	656	507	335	142
7	801	729	627	500	347	172	.97975
8	660	584	478	346	189	009	808
9	524	442	331	193	031	.97846	641
10	393	304	187	043	.97875	685	475
11	267	171	047	.97897	723	527	312
12	145	041	.97910	753	573	371	150
13	026	.97914	775	611	424	216	.96989
14	.97911	790	643	472	278	063	829
15	800	669	514	334	133	.96911	670
16	692	552	387	199	.96990	760	512
17	583	433	259	062	844	607	352
18	473	313	129	.96923	697	452	189
19	363	191	.96997	782	547	294	023
20	252	068	864	639	395	134	.95856
21	139	.96944	729	495	242	.95973	687
22	024	818	592	348	087	809	516
23	.96907	689	453	199	.95929	643	343
24	787	558	312	048	769	476	168
25	665	424	168	.95895	607	306	.94991
26	539	287	020	738	442	133	810
27	406	144	.95867	576	272	.94955	625
28	268	.95996	710	410	098	774	438
29	125	844	548	241	.94922	590	248
30	.95977	686	382	067	741	403	055
31	823	524	212	.94890	557	214	.93860
32	665	357	038	709	370	021	662
33	502	186	.94860	525	180	.93825	461
34	334	011	679	337	.93986	626	257
35	162	.94832	494	146	790	425	051
36	.94986	650	306	.93952	591	221	.92843
37	805	464	114	756	390	016	634
38	620	273	.93919	556	186	.92808	422
39	431	079	720	353	.92979	597	208
40	238	.93882	518	148	770	385	.91992
41	042	682	314	.92940	558	170	774
42	.93842	478	107	729	344	.91952	554
43	639	271	.92897	516	128	733	332
44	433	062	685	301	.91910	513	108
45	226	.92852	472	085	692	291	.90884
46	017	640	257	.91868	472	069	660
47	.92806	426	041	649	250	.90845	434
48	593	211	.91823	429	028	621	207
49	379	.91995	604	208	.90805	396	.89979
50	162	776	384	.90985	580	168	750

DENSITY OF MIXTURES OF ETHYL ALCOHOL AND WATER IN GRAMS PER MILLILITER.

Per cent C_2H_5OH by weight	Temperature.						
	10° C.	15° C.	20° C.	25° C.	30° C.	35° C.	40° C.
50	0.92162	0.91776	0.91384	0.90985	0.90580	0.90168	0.89750
51	.91943	555	160	760	353	.89940	519
52	723	333	.90936	534	125	710	288
53	502	110	711	307	.89896	479	056
54	279	.90885	485	079	667	248	.88823
55	055	659	258	.89850	437	016	589
56	.90831	433	031	621	206	.88784	356
57	607	207	.89803	392	.88975	552	122
58	381	.89980	574	162	744	319	.87888
59	154	752	344	.88931	512	085	653
60	.89927	523	113	699	278	.87851	417
61	698	293	.88882	466	044	615	180
62	468	062	650	233	.87809	379	.86943
63	237	.88830	417	.87998	574	142	705
64	006	597	183	763	337	.86905	466
65	.88774	364	.87948	527	100	667	227
66	541	130	713	291	.86863	429	.85987
67	308	.87895	477	054	625	190	747
68	074	660	241	.86817	387	.85950	507
69	.87839	424	004	579	148	710	266
70	602	187	.86766	340	.85908	470	025
71	365	.86949	527	100	667	228	.84783
72	127	710	287	.85859	426	.84986	540
73	.86888	470	047	618	184	743	297
74	648	229	.85806	376	.84941	500	053
75	408	.85988	564	134	698	257	.83809
76	168	747	322	.84891	455	013	564
77	.85927	505	079	647	211	.83768	319
78	685	262	.84835	403	.83966	523	074
79	442	018	590	158	720	277	.82827
80	197	.84772	344	.83911	473	029	578
81	.84950	525	096	664	224	.82780	329
82	702	277	.83848	415	.82974	530	079
83	453	028	599	164	724	279	.81828
84	203	.83777	348	.82913	473	027	576
85	.83951	525	095	660	220	.81774	322
86	697	271	.82840	405	.81965	519	067
87	441	014	583	148	708	262	.80811
88	181	.82754	323	.81888	448	003	552
89	.82919	492	062	626	186	.80742	291
90	654	227	.81797	362	.80922	478	028
91	386	.81959	529	094	655	211	.79761
92	114	688	257	.80823	384	.79941	491
93	.81839	413	.80983	549	111	669	220
94	561	134	705	272	.79835	393	.78947
95	278	.80852	424	.79991	555	114	670
96	.80991	566	138	706	271	.78831	388
97	698	274	.79846	415	.78981	542	100
98	399	.79975	547	117	684	247	.77806
99	094	670	243	.78814	382	.77946	507
100	.79784	360	.78934	506	075	641	203

Table 76.

DENSITIES OF AQUEOUS MIXTURES OF METHYL ALCOHOL, CANE SUGAR, OR SULPHURIC ACID.

Per cent by weight of substance.	Methyl Alcohol. $D\frac{15^\circ}{4^\circ}$ C.	Cane Sugar. 20°	Sulphuric Acid. $D\frac{20^\circ}{4^\circ}$ C.	Per cent by weight of substance.	Methyl Alcohol. $D\frac{15^\circ}{4^\circ}$ C.	Cane Sugar. 20°	Sulphuric Acid. $D\frac{20^\circ}{4^\circ}$ C.
0	0.99913	0.998234	0.99823	50	0.91852	1.229567	1.39505
1	.99727	1.002120	1.00506	51	.91653	1.235085	1.40487
2	.99543	1.006015	1.01178	52	.91451	1.240641	1.41481
3	.99370	1.009934	1.01839	53	.91248	1.246234	1.42487
4	.99198	1.013881	1.02500	54	.91044	1.251866	1.43503
5	.99029	1.017854	1.03168	55	.90839	1.257535	1.44530
6	.98864	1.021855	1.03843	56	.90631	1.263243	1.45568
7	.98701	1.025885	1.04527	57	.90421	1.268989	1.46615
8	.98547	1.029942	1.05216	58	.90210	1.274774	1.47673
9	.98394	1.034029	1.05909	59	.89996	1.280595	1.48740
10	.98241	1.038143	1.06609	60	.89781	1.286456	1.49818
11	.98093	1.042288	1.07314	61	.89563	1.292354	1.50904
12	.97945	1.046462	1.08026	62	.89341	1.298291	1.51999
13	.97802	1.050665	1.08744	63	.89117	1.304267	1.53102
14	.97660	1.054900	1.09468	64	.88890	1.310282	1.54213
15	.97518	1.059165	1.10199	65	.88662	1.316334	1.55333
16	.97377	1.063460	1.10936	66	.88433	1.322425	1.56460
17	.97237	1.067789	1.11679	67	.88203	1.328554	1.57595
18	.97096	1.072147	1.12428	68	.87971	1.334722	1.58739
19	.96955	1.076537	1.13183	69	.87739	1.340928	1.59890
20	.96814	1.080959	1.13943	70	.87507	1.347174	1.61048
21	.96673	1.085414	1.14709	71	.87271	1.353456	1.62213
22	.96533	1.089900	1.15480	72	.87033	1.359778	1.63384
23	.96392	1.094420	1.16258	73	.86792	1.366139	1.64560
24	.96251	1.098971	1.17041	74	.86546	1.372536	1.65738
25	.96108	1.103557	1.17830	75	.86300	1.378971	1.66917
26	.95963	1.108175	1.18624	76	.86051	1.385446	1.68095
27	.95817	1.112828	1.19423	77	.85801	1.391956	1.69268
28	.95668	1.117512	1.20227	78	.85551	1.398505	1.70433
29	.95518	1.122231	1.21036	79	.85300	1.405091	1.71585
30	.95366	1.126984	1.21850	80	.85048	1.411715	1.72717
31	.95213	1.131773	1.22669	81	.84794	1.418374	1.73827
32	.95056	1.136596	1.23492	82	.84536	1.425072	1.74904
33	.94896	1.141453	1.24320	83	.84274	1.431807	1.75943
34	.94734	1.146345	1.25154	84	.84009	1.438579	1.76932
35	.94570	1.151275	1.25992	85	.83742	1.445388	1.77860
36	.94404	1.156238	1.26836	86	.83475	1.452232	1.78721
37	.94237	1.161236	1.27685	87	.83207	1.459114	1.79509
38	.94067	1.166269	1.28543	88	.82937	1.466032	1.80223
39	.93894	1.171340	1.29407	89	.82667	1.472986	1.80864
40	.93720	1.176447	1.30278	90	.82396	1.479976	1.81438
41	.93543	1.181592	1.31157	91	.82124	1.487002	1.81950
42	.93365	1.186773	1.32043	92	.81849	1.494063	1.82401
43	.93185	1.191993	1.32938	93	.81568	1.501158	1.82790
44	.93001	1.197247	1.33843	94	.81285	1.508289	1.83115
45	.92815	1.202540	1.34759	95	.80999	1.515455	1.83368
46	.92627	1.207870	1.35686	96	.80713	1.522656	1.83548
47	.92436	1.213238	1.36625	97	.80428	1.529891	1.83637
48	.92242	1.218643	1.37574	98	.80143	1.537161	1.83605
49	.92048	1.224086	1.38533	99	.79859	1.544462	
50	.91852	1.229567	1.39505	100	.79577	1.551800	

(1) Calculated from the specific gravity determinations of Doroschevski and Rozhdestvenski at 15°/15° C.; J. Russ., Phys. Chem. Soc., 41, p. 977, 1909.
(2) According to Dr. F. Plato; Wiss. Abh. der K. Normal-Eichungs-Kommission, 2, p. 153, 1900.
(3) Calculated from Dr. Domke's table; Wiss. Abh. der K. Normal-Eichungs-Kommission, 5, p. 131, 1900.

All reprinted from Circular 19, U.S. Bureau of Standards, 1913.

VELOCITY OF SOUND IN SOLIDS.

The numbers given in this table refer to the velocity of sound along a bar of the substance, and hence depend on the Young's Modulus of elasticity of the material. The elastic constants of most of the materials given in this table vary through a somewhat wide range, and hence the numbers can only be taken as rough approximations to the velocity which may be obtained in any particular case. When temperatures are not marked, between 10° and 20° is to be understood.

Substance.	Temp. C.	Velocity in meters per second.	Velocity in feet per second.	Authority.
Metals: Aluminum	–	5104	16740	Masson.
Brass	–	3500	11480	Various.
Cadmium	–	2307	7570	Masson.
Cobalt	–	4724	15500	"
Copper	20	3560	11670	Wertheim.
"	100	3290	10800	"
"	200	2950	9690	"
Gold (soft)	20	1743	5717	"
" (hard)	–	2100	6890	Various.
Iron and soft steel	–	5000	16410	"
Iron	20	5130	16820	Wertheim.
"	100	5300	17390	"
"	200	4720	15480	"
" cast steel	20	4990	16360	"
" " "	200	4790	15710	"
Lead	20	1227	4026	"
Magnesium	–	4602	15100	Melde.
Nickel	–	4973	16320	Masson.
Palladium	–	3150	10340	Various.
Platinum	20	2690	8815	Wertheim.
"	100	2570	8437	"
"	200	2460	8079	"
Silver	20	2610	8553	"
"	100	2640	8658	"
Tin	–	2500	8200	Various.
Zinc	–	3700	12140	"
Various: Brick	–	3652	11980	Chladni.
Clay rock	–	3480	11420	Gray & Milne.
Cork	–	500	1640	Stefan.
Granite	–	3950	12960	Gray & Milne.
Marble	–	3810	12500	"
Paraffin	15	1304	4280	Warburg.
Slate	–	4510	14800	Gray & Milne.
Tallow	16	390	1280	Warburg.
Tuff	–	2850	9350	Gray & Milne.
Glass from	–	5000	16410	Various.
Glass to	–	6000	19690	"
Ivory	–	3013	9886	Ciccone & Campanile.
Vulcanized rubber (black)	0	54	177	Exner.
Vulcanized rubber (black)	50	31	102	"
" " (red)	0	69	226	"
" " "	70	34	111	"
Wax	17	880	2890	Stefan.
"	28	441	1450	"
Woods: Ash, along the fibre	–	4670	15310	Wertheim.
" across the rings	–	1390	4570	"
" along the rings		1260	4140	"
Beech, along the fibre		3340	10960	"
" across the rings		1840	6030	"
" along the rings		1415	4640	"
Elm, along the fibre	–	4120	13516	"
" across the rings	–	1420	4665	"
" along the rings	–	1013	3324	"
Fir, along the fibre	–	4640	15220	"
Maple "	–	4110	13470	"
Oak "	–	3850	12620	"
Pine "	–	3320	10900	"
Poplar "	–	4280	14050	"
Sycamore "	–	4460	14640	"

TABLE 78.

VELOCITY OF SOUND IN LIQUIDS AND GASES.

For gases, the velocity of sound $= \sqrt{\gamma P/\rho}$, where P is the pressure, ρ the density, and γ the ratio of specific heat at constant pressure to that at constant volume (see Table 265).

Substance.	Temp. C.	Velocity in meters per second.	Velocity in feet per second.	Authority.
Liquids: Alcohol, 95%	12.5°	1241.	4072.	Dorsing, 1908.
"	20.5	1213.	3980.	"
Ammonia, conc.	16.	1663.	5456.	"
Benzol	17.	1166.	3826.	"
Carbon bisulphide	15.	1161.	3809.	"
Chloroform	15.	983.	3225.	"
Ether	15.	1032.	3386.	"
NaCl, 10% sol.	15.	1470.	4823.	"
" 15% "	15.	1530.	5020.	"
" 20% "	15.	1650.	5414.	"
Turpentine oil	15.	1326.	4351.	"
Water, air-free	13.	1441.	4728.	"
" " "	19.	1461.	4794.	"
" " "	31.	1505.	4938.	"
" Lake Geneva	9.	1435.	4708.	Colladon-Sturm.
" Seine river	15.	1437.	4714.	Wertheim.
" " "	30.	1528.	5013.	"
" " "	60.	1724.	5657.	"
Gases: Air, dry, CO_2-free	0.	331.78	1088.5	Rowland.
" "	0.	331.36	1087.1	Violle, 1900.
" " CO_2-free	0.	331.92	1089.0	Thiesen, 1908.
" 1 atmosphere	0.	331.7	1088.	Mean.
" 25 "	0.	332.0	1089.	" (Witkowski).
" 50 "	0.	334.7	1098.	" "
" 100 "	0.	350.6	1150.	" "
"	20.	344.	1129.	
"	100.	386.	1266.	Stevens.
"	500.	553.	1814.	"
"	1000.	700.	2297.	"
Ammonia	0.	415.	1361.	Masson.
Carbon monoxide	0.	337.1	1106.	Wullner.
" "	0.	337.4	1107.	Dulong.
" dioxide	0.	258.0	846.	Brockendahl, 1906.
" disulphide	0.	189.	620.	Masson.
Chlorine	0.	206.4	677.	Martini.
"	0.	205.3	674.	Strecker.
Ethylene	0.	314.	1030.	Dulong.
Hydrogen	0.	1269.5	4165.	"
"	0.	1286.4	4221.	Zoch.
Illuminating gas	0.	490.4	1609.	"
Methane	0.	432.	1417.	Masson.
Nitric oxide	0.	325.	1066.	"
Nitrous oxide	0.	261.8	859.	Dulong.
Oxygen	0.	317.2	1041.	"
Vapors: Alcohol	0.	230.6	756.	Masson.
Ether	0.	179.2	588.	"
Water	0.	401.	1315.	"
"	100.	404.8	1328.	Treitz, 1903.
"	130.	424.4	1392.	"

NOTE: The values from Ammonia to Methane inclusive are for closed tubes.

MUSICAL SCALES.

The pitch relations between two notes may be expressed precisely (1) by the ratio of their vibration frequencies; (2) by the number of equally-tempered semitones between them (E. S.); also, less conveniently, (3) by the common logarithm of the ratio in (1); (4) by the lengths of the two portions of the tense string which will furnish the notes; and (5) in terms of the octave as unity. The ratio in (4) is the reciprocal of that in (1); the number for (5) is 1/12 of that for (2); the number for (2) is nearly 40 times that for (3).

Table 79 gives data for the middle octave, including vibration frequencies for three standards of pitch; $a = 435$ double vibrations per second, is the international standard and was adopted by the American Piano Manufacturers' Association. The "just-diatonic scale" of C-major is usually deduced, following Chladni, from the ratios of the three perfect major triads reduced to one octave, thus:

			4	:	5	:	6				
4	:	5	:	6		4	:	5	:	6	
F		A		C	E	G		B		D	
16		20		24	30	36		45		54	
				24 27	30 32	36 40		45 48			

Other equivalent ratios and their values in E. S. are given in Table 80. By transferring D to the left and using the ratio 10 : 12 : 15 the scale of A-minor is obtained, which agrees with that of C-major except that D = 26 2/3. Nearly the same ratios are obtained from a series of harmonics beginning with the eighth; also by taking 12 successive perfect or Pythagorean fifths or fourths and reducing to one octave. Such calculations are most easily made by adding and subtracting intervals expressed in E. S. The notes needed to furnish a just major scale in other keys may be found by successive transpositions by fifths or fourths as shown in Table 80. Disregarding the usually negligible difference of 0.02 E. S., the table gives the 24 notes to the octave required in the simplest enharmonic organ; the notes fall into pairs that differ by a comma, 0.22 E. S. The line "mean tone" is based on Dom Bedos' rule for tuning the organ (1746). The tables have been checked by the data in Ellis' Helmholtz's "Sensations of Tone."

TABLE 79.

Note.	Interval. Tempered.	Interval. Just.	Ratios. Just.	Ratios. Tempered.	Logarithms. Just.	Logarithms. Tempered.	Number of Vibrations per second. Just.	Just.	Just.	Tempered.	Beats for 0.1 E. S.
	E. S.	E. S.									
c′	0	0.	1.00	1.00000	0.0000	0.00000	*256*	*264*	258.7	258.7	1.50
	1			1.05926		.02509				274.0	
d′	2	2.04	1.125	1.12246	.05115	.05017	288	297	291.0	290.3	1.68
	3			1.18921		.07526				307.6	
e′	4	3.86	1.25	1.25992	.09691	.10034	320	330	323.4	325.9	1.89
f′	5	4.98	1.33	1.33484	.12494	.12543	341.3	352	344.9	345.3	2.00
	6			1.41421		.15051				365.8	
g′	7	7.02	1.50	1.49831	.17609	.17560	384	396	388	387.5	2.25
	8			1.58740		.20069				410.6	
a′	9	8.84	1.67	1.68179	.22185	.22577	426.7	*440*	431.1	*435.0*	2.52
	10			1.78180		.25086				460.9	
b′	11	10.88	1.875	1.88775	.27300	.27594	480	495	485.0	488.3	2.83
c″	12	12.00	2.00	2.00000	.30103	.30103	512	528	517.3	517.3	3.00

TABLE 80.

Key of		C		D		E	F		G		A		B	C
7 #s	C#		1.14		3.18		5.00	6.12		8.16		9.98		12.02
			0.92		2.96		4.78	5.90		7.94		9.76		11.80
6 "	F#		1.14		2.96		5.00	6.12		8.16		9.98	11.10	
			0.92		2.74		4.78	5.90		7.94		9.76	10.88	
5 "	B		1.14		2.96	4.08		6.12		7.94		9.98	11.10	
			0.92		2.74	3.86		5.90		7.72		9.76	10.88	
4 "	E		0.92		2.96	4.08		6.12		7.94	9.06		11.10	
			0.70		2.74	3.86		5.90		7.72	8.84		10.88	
3 "	A		0.92	2.04		4.08		5.90		7.94	9.06		11.10	
			0.70	1.82		3.86		5.68		7.72	8.84		10.88	
2 "	D		0.92	2.04		4.08		5.90	7.02		9.06		10.88	
1 #	G	0.00		2.04		3.86		5.90	7.02		9.06		10.88	12.00
	C	0.00		2.04		3.86	4.98		7.02		8.84		10.88	12.00
1 ♭	F	0.00		1.82		3.86	4.98		7.02		8.84	9.96		12.00
2 ♭s	B♭	0.00		1.82	2.94		4.98		6.80		8.84	9.96		12.00
3 "	E♭	−.22		1.82	2.94		4.98		6.80	7.92		9.96		11.78
4 "	A♭	−.22	0.90		2.94		4.76		6.80	7.92		9.96		11.78
5 "	D♭	−.22	0.90		2.94		4.76	5.88		7.92		9.74		11.78
6 "	G♭		0.90		2.72		4.76	5.88		7.92		9.74	10.86	
7 "	C♭		0.90		2.72	3.84		5.88		7.70		9.74	10.86	
Harmonic Series		8 0.0	(1.71 1.05)	9 2.04	(19 2.98)	10 3.86	(21 4.70)	11 5.51	12 7.02	(25 7.73)	13 8.41	14 9.69	15 10.88	16 12.00
Cycle of fifths		0.0	1.14	2.04	3.18	4.08	5.22	6.12	7.02	8.16	9.06	10.20	11.10	12.24
Cycle of fourths		0.0	0.90	1.80	2.94	3.84	4.98	5.88	6.78	7.92	8.82	9.96	10.86	11.76
Mean tone		0.0	0.76	1.93	3.11	3.86	5.03	5.79	6.97	7.72	8.90	10.07	10.83	12.00
Equal 7 step		0.0		1.71	3 43		5.14		6.86		8.57	10.29		12.00

TABLE 81.

ACCELERATION OF GRAVITY.

For Sea Level and Different Latitudes.

Calculated from Helmert's formula :

$$g = 9^{m}.78030\,(1 + 0.005302 \sin^2 \Phi - 0.000007 \sin^2 2\Phi)$$

Latitude Φ	g cm. per sec. per sec.	Log. g	g feet per sec. per sec.	Latitude Φ	g cm. per sec. per sec.	Log. g	g feet per sec. per sec.
0°	978.030	2.9903522	32.0875	50°	981.066	2.9916982	32.1871
5	.069	.9903695	.0888	51	.155	.9917376	.1901
10	.186	.9904214	.0927	52	.244	.9917770	.1930
12	.253	.9904512	.0949	53	.331	.9918156	.1959
14	.332	.9904863	.0974	54	.418	.9918540	.1987
15	978.376	2.9905058	32.0989	55	981.503	2.9918916	32.2015
16	.422	.9905262	.1004	56	.588	.9919292	.2043
17	.471	.9905480	.1020	57	.672	.9919664	.2070
18	.523	.9905710	.1037	58	.754	.9920027	.2097
19	.577	.9905950	.1055	59	.835	.9920385	.2124
20	978.634	2.9906203	32.1074	60	981.914	2.9920735	32.2150
21	.693	.9906465	.1093	61	.992	.9921080	.2175
22	.754	.9906736	.1113	62	982.068	.9921415	.2200
23	.818	.9907019	.1134	63	.142	.9921743	.2224
24	.884	.9907313	.1156	64	.215	.9922066	.2248
25	978.952	2.9907614	32.1178	65	982.285	2.9922375	32.2271
26	979.022	.9907925	.1201	66	.354	.9922680	.2294
27	.094	.9908244	.1224	67	.420	.9922972	.2316
28	.168	.9908572	.1249	68	.485	.9923259	.2337
29	.244	.9908909	.1274	69	.546	.9923529	.2357
30	979.321	2.9909250	32.1299	70	982.606	2.9923794	32.2377
31	.400	.9909601	.1325	71	.663	.9924046	.2395
32	.481	.9909960	.1351	72	.718	.9924289	.2413
33	.562	.9910319	.1378	73	.770	.9924519	.2430
34	.646	.9910691	.1406	74	.820	.9924740	.2447
35	979.730	2.9911064	32.1433	75	982.866	2.9924943	32.2462
36	.815	.9911441	.1461	76	.911	.9925142	.2477
37	.902	.9911827	.1490	77	.952	.9925323	.2490
38	.989	.9912212	.1518	78	.990	.9925491	.2503
39	980 077	.9912602	.1547	79	983.026	.9925650	.2514
40	980.166	2.9912996	32.1576	80	983.058	2.9925791	32.2525
41	.255	.9913391	.1605	81	.088	.9925924	.2535
42	.345	.9913789	.1635	82	.115	.9926043	.2544
43	.435	.9914188	.1664	83	.138	.9926145	.2551
44	.525	.9914587	.1694	84	.159	.9926238	.2558
45	980.616	2.9914989	32.1724	85	983.176	2.9926312	32.2564
46	.706	.9915388	.1753	86	.190	.9926375	.2568
47	.797	.9915791	.1783	87	.201	.9926423	.2572
48	.887	.9916190	.1813	88	.209	.9926459	.2574
49	.977	.9916588	.1842	90	.216	.9926489	.2577

To reduce log. g (cm. per sec. per sec.) to log. g (ft. per sec. per sec.) add log. 0.03280833 = 8.5159842 — 10.

CORRECTION FOR ALTITUDE.

— 0.0003086 cm. per meter when altitude is in meters.
— 0.000003086 ft. per foot when altitude is in feet.

Altitude.	Correction.	Altitude.	Correction.
200 m.	0.0617 cm./sec.^{2}	200 ft.	0.000617 ft./sec.^{2}
300	.0926	300	.000926
400	.1234	400	.001234
500	.1543	500	.001543
600	.1852	600	.001852
700	.2160	700	.002160
800	.2469	800	.002469
900	.2777	900	.002777

Table 82.
GRAVITY.

In this table the results of a number of the more recent gravity determinations are brought together. They serve to show the degree of accuracy which may be assumed for the numbers in Table 81. In general, gravity is a little lower than the calculated value for stations far inland and slightly higher on the coast line.

Place.	Latitude. N. +, S. —.	Elevation in meters.	Gravity, $\frac{cm.}{sec^2}$ Observed.	Gravity, $\frac{cm.}{sec^2}$ Reduced to sea level.	Reference.
Singapore	1° 17′	14	978.08	978.08	1
Georgetown, Ascension	—7 56	5	978.25	978.25	2
Green Mountain, Ascension	—7 57	686	978.10	978.23	2
Loanda, Angola	—8 49	46	978.15	978.16	2
Caroline Islands	—10 00	2	978.37	978.37	3
Bridgetown, Barbadoes	13 04	18	978.18	978.18	2
Jamestown, St. Helena	—15 55	10	978.67	978.67	2
Longwood, "	—15 57	533	978.53	978.59	2
Pakaoao, Sandwich Islands	20 43	3001	978.28	978.85	3
Lahaina, " "	20 52	3	978.86	978.86	3
Haiki, " "	20 56	117	978.91	978.93	3
Honolulu, " "	21 18	3	978.97	978.97	3
St. Georges, Bermuda	32 23	2	979.77	979.77	2
Sidney, Australia	—33 52	43	979.68	979.69	1
Cape Town	—33 56	11	979.62	979.62	2
Tokio, Japan	35 41	6	979.95	979.95	1
Auckland, New Zealand	—36 52	43	979.68	979.69	1
Mount Hamilton, Cal. (Lick Obs.)	37 20	1282	979.66	979.91	4
" " " "	37 20	1282	979.68	979.92	5
San Francisco, Cal.	37 47	114	979.96	979.98	4
" " "	37 47	114	980.02	980.04	5
Washington, D. C.*	38 53	10	980.11	980.11	4
Denver, Colo.	39 54	1645	979.68	979.98	5
York, Pa.	39 58	122	980.12	980.14	6
Ebensburgh, Pa.	40 27	651	980.08	980.20	6
Allegheny, Pa.	40 28	348	980.09	980.15	6
Hoboken, N. J.	40 44	11	980.27	980.27	4
Salt Lake City, Utah	40 46	1288	979.82	980.05	5
Chicago, Ill.	41 49	165	980.34	980.37	5
Pampaluna, Spain	42 49	450	980.34	980.42	7
Montreal, Canada	45 31	100	980.73	980.75	5
Geneva, Switzerland	46 12	405	980.58	980.64	8
" "	46 12	405	980.60	980.66	9
Berne, "	46 57	572	980.61	980.69	9
Zurich, "	47 23	466	980.67	980.74	9
Paris, France	48 50	67	980.96	980.97	8
Kew, England	51 28	7	981.20	981.20	8
Berlin, Germany	52 30	49	981.26	981.27	8
Port Simpson, B. C.	54 34	6	981.46	981.46	4
Burroughs Bay, Alaska	55 59	0	981.51	981.51	4
Wrangell, "	56 28	7	981.60	981.60	4
Sitka, "	57 03	8	981.69	981.69	4
St. Paul's Island, "	57 07	12	981.67	981.67	4
Juneau, "	58 18	5	981.74	981.74	4
Pyramid Harbor, "	59 10	5	981.82	981.82	4
Yakutat Bay, "	59 32	4	981.83	981.83	4

1 Smith: "United States Coast and Geodetic Survey Report for 1884," App. 14.
2 Preston: "United States Coast and Geodetic Survey Report for 1890," App. 12.
3 Preston: Ibid. 1888, App. 14.
4 Mendenhall: Ibid. 1891, App. 15.
5 Defforges: "Comptes Rendus," vol. 118, p. 231.
6 Pierce: "U. S. C. and G. S. Rep. 1883," App. 19.
7 Cebrian and Los Arcos: "Comptes Rendus des Séances de la Commission Permanente de l'Association Géodesique International," 1893.
8 Pierce: "U. S. C. and G. S. Report 1876, App. 15, and 1881, App. 17."
9 Messerschmidt: Same reference as 7.

* For references 1-4, values are derived by comparative experiments with invariable pendulums, the value for Washington taken as 980.111. For the latter see Appendix 5 of the Coast and Geodetic Survey Report for 1901.

SUMMARY OF RESULTS OF THE VALUE OF GRAVITY (g) AT STATIONS IN THE UNITED STATES AND ALASKA.*

Station.	Latitude.	Longitude.	Elevation.	g observed.
	° ′ ″	° ′ ″	Meters.	cm./sec.^{2}
Calais, Me.	45 11 11	67 16 54	38	980.630
Boston, Mass.	42 21 33	71 03 50	22	980.395
Cambridge, Mass.	42 22 48	71 07 45	14	980.397
Worcester, Mass.	42 16 29	71 48 28	170	980.323
New York, N. Y.	40 48 27	73 57 43	38	980.266
Princeton, N. J.	40 20 57	74 39 28	64	980.177
Philadelphia, Pa.	39 57 06	75 11 40	16	980.195
Ithaca, N. Y.	42 27 04	76 29 00	247	980.299
Baltimore, Md.	39 17 50	76 37 30	30	980.096
Washington, C. & G. S.	38 53 13	77 00 32	14	980.111
Washington, Smithsonian	38 53 20	77 01 32	10	980.113
Charlottesville, Va.	38 02 01	78 30 16	166	979.937
Deer Park, Md.	39 25 02	79 19 50	770	979.934
Charleston, S. C.	32 47 14	79 56 03	6	979.545
Cleveland, Ohio	41 30 22	81 36 38	210	980.240
Key West, Fla.	24 33 33	81 48 25	1	978.969
Atlanta, Ga.	33 44 58	84 23 18	324	979.523
Cincinnati, Ohio	39 08 20	84 25 20	245	980.003
Terre Haute, Ind.	39 28 42	87 23 49	151	980.071
Chicago, Ill.	41 47 25	87 36 03	182	980.277
Madison, Wis. (Univ. of Wis.)	43 04 35	89 24 00	270	980.364
New Orleans, La.	29 56 58	90 04 14	2	979.323
St. Louis, Mo.	38 38 03	90 12 13	154	980.000
Little Rock, Ark.	34 44 57	92 16 24	89	979.720
Kansas City, Mo.	39 05 50	94 35 21	278	979.989
Galveston, Tex.	29 18 12	94 47 29	3	979.271
Austin, Texas (University)	30 17 11	97 44 14	189	979.282
Austin, Texas (Capitol)	30 16 30	97 44 16	170	979.287
Ellsworth, Kan.	38 43 43	98 13 32	469	979.925
Laredo, Tex.	27 30 29	99 31 12	129	979.081
Wallace, Kan.	38 54 44	101 35 26	1005	979.754
Colorado Springs, Col.	38 50 44	104 49 02	1841	979.489
Denver, Col.	39 40 36	104 56 55	1638	979.608
Pike's Peak, Col.	38 50 20	105 02 02	4293	978.953
Gunnison, Col.	38 32 33	106 56 02	2340	979.341
Grand Junction, Col.	39 04 09	108 33 56	1398	979.632
Green River, Utah	38 59 23	110 09 56	1243	979.635
Grand Canyon, Wyo.	44 43 16	110 29 44	2386	979.898
Norris Geyser Basin, Wyo.	44 44 09	110 42 02	2276	979.949
Lower Geyser Basin, Wyo.	44 33 21	110 48 08	2200	979.931
Pleasant Valley Jct., Utah	39 50 47	111 00 46	2191	979.511
Salt Lake City, Utah	40 46 04	111 53 46	1322	979.802
Ft. Egbert, Eagle, Alaska	64 47 22	141 12 24	174	982.182

* All the values in this table depend on relative determination of gravity and an adopted value for gravity at Washington (Coast and Geodetic Survey Office) of 980.111. This adopted value was the result of the determination in 1900 of the relative value of gravity at Potsdam and at Washington. See footnote on previous page.

LENGTH OF THE SECONDS PENDULUM.

TABLE 84. — Length of Seconds Pendulum at Sea Level for Different Latitudes.*

Latitude.	Length in centimeters.	Log.	Length in inches.	Log.	Latitude.	Length in centimeters.	Log.	Length in inches.	Log.
0	99.0950	1.996052	39.0131	1.591218	50	99.4027	1.997398	39.1348	1.592563
5	.0989	6069	.0152	1234	55	.4471	7592	.1524	2758
10	.1108	6121	.0200	1287	60	.4888	7774	.1687	2939
15	.1302	6206	.0274	1372	65	.5263	7938	.1835	3103
20	.1562	6320	.0378	1485	70	.5587	8079	.1962	3244
25	99.1884	1.996461	39.0506	1.591627	75	99.5850	1.998194	39.2067	1.593360
30	.2259	6625	.0652	1790	80	.6045	8279	.2143	3444
35	.2672	6806	.0816	1972	85	.6165	8331	.2190	3496
40	.3116	7000	.0990	2166	90	.6206	8349	.2206	3514
45	.3571	7199	.1169	2364					

* Calculated from force of gravity table by the formula $l = g/\pi^2$. For each 100 feet of elevation subtract 0.000596 centimeters, or 0.000235 inches, or .0000196 feet.

TABLE 85. — Length of the Seconds Pendulum.*

Date of determination.	Number of observation stations.	Range of latitude included by the stations.	Length of pendulum in meters. for latitude ϕ.	Corresponding length of pendulum for lat. 45°	Reference.
1799	15	From +67° 05′ to −33° 56′	$0.990631 + .005637 \sin^2\phi$	0.993450	1
1816	31	" +74° 53′ " −51° 21′	$0.990743 + .005466 \sin^2\phi$	0.993976	2
1821	8	" +38° 40′ " −60° 45′	$0.990880 + .005340 \sin^2\phi$	0.993550	3
1825	25	" +79° 50′ " −12° 59′	$0.990977 + .005142 \sin^2\phi$	0.993548	4
1827	41	" +79° 50′ " −51° 35′	$0.991026 + .005072 \sin^2\phi$	0.993562	5
1829	5	" 0° 0′ " +67° 04′	$0.990555 + .005679 \sin^2\phi$	0.993395	6
1830	49	" +79° 51′ " −51° 35′	$0.991017 + .005087 \sin^2\phi$	0.993560	7
1833	—	" — " —	$0.990941 + .005142 \sin^2\phi$	0.993512	8
1869	51	" +79° 50′ " −51° 35′	$0.990970 + .005185 \sin^2\phi$	0.993554†	9
1876	73	" +79° 50′ " −62° 56′	$0.991011 + .005105 \sin^2\phi$	0.993563	10
1884	123	" +79° 50′ " −62° 56′	$0.990918 + .005262 \sin^2\phi$	0.993549	11
Combining the above results			$0.990910 + .005290 \sin^2\phi$	0.993555	12

1 Laplace: "Traité de Mécanique Céleste," T. 2, livre 3, chap. 5, sect. 42.
2 Mathieu: "Sur les expériences du pendule;" in "Connaissance des Temps 1816." Additions, pp. 314–341, p. 332.
3 Biot et Arago: "Recueil d'Observations géodésiques, etc." Paris, 1821, p. 575.
4 Sabine: "An Account of Experiments to determine the Figure of the Earth, etc., by Sir Edward Sabine." London, 1825, p. 352.
5 Saigey: "Comparaison des Observations du pendule à diverses latitudes; faites par MM. Biot, Kater, Sabine, de Freycinet, et Duperry;" in "Bulletin des Sciences Mathématiques, etc.," T. 1, pp. 31–43, and 171–184. Paris, 1827.
6 Pontécoulant: "Théorie analytique du Système du monde," Paris, 1829, T. 2, p. 466.
7 Airy: "Figure of the Earth;" in "Encyc. Met." 2d Div. vol. 3, p. 230.
8 Poisson: "Traité de Mécanique," T. 1, p. 377; "Connaissance des Temps," 1834, pp. 32–33; and Puissant: "Traité de géodésie," T. 2, p. 464.
9 Unferdinger: "Das Pendel als geodätisches Instrument;" in Grunert's "Archiv," 1869, p. 316.
10 Fischer: "Die Gestalt der Erde und die Pendelmessungen;" in "Ast. Nach." 1876, col. 87.
11 Helmert: "Die mathematischen und physikalischen Theorieen der höheren Geodäsie, von Dr. F. R. Helmert," II. Theil. Leipzig, 1884, p. 241.
12 Harkness.

* The data here given with regard to the different determinations which have been made of the length of the seconds pendulum are quoted from Harkness (Solar Parallax and its Related Constants, Washington, 1891).
† Calculated from a logarithmic expression given by Unferdinger.

MISCELLANEOUS GEODETIC DATA.*

TABLE 86.

Length of the seconds pendulum at sea level $= l = 39.012540 + 0.208268 \sin^2 \phi$ inches.
$= 3.251045 + 0.017356 \sin^2 \phi$ feet.
$= 0.9909910 + 0.005290 \sin^2 \phi$ meters.

Acceleration produced by gravity per second per second mean solar time . . . $= g = 32.086528 + 0.171293 \sin^2 \phi$ feet.
$= 977.9886 + 5.2210 \sin^2 \phi$ centimeters.

	Clarke Spheroid.	U. S. C. & G. Survey.
Equatorial radius	$= a =$ 6378206 meters; 3963.225 miles.	6378388 ± 18 meters; 3963.339 miles.
Polar semi-diameter	$= b =$ 6356584 meters; 3949.790 miles.	6356909 meters; 3949.992 miles.
Reciprocal of flattening	$= \frac{a}{a-b} = 295.0$	297.0 ± 0.5
Square of eccentricity	$= e^2 = \frac{a^2 - b^2}{a^2} = 0.006768658$	0.0067237 ± 0.0000120.

Difference between geographical and geocentric latitude $= \phi - \phi' =$
$688.2242'' \sin 2\phi - 1.1482'' \sin 4\phi + 0.0026'' \sin 6\phi$.

Mean density of the Earth = 5.5247 ± 0.0013 (Burgess Phys. Rev. 1902).

Continental surface density of the Earth = 2.67 } Harkness.
Mean density outer ten miles of earth's crust = 2.40 }

Moments of inertia of the Earth; the principal moments being taken as A, B, and C, and C the greater:

$$\frac{C-A}{C} = 0.00326521 = \frac{1}{306.259};$$
$$C - A = 0.001064767\, Ea^2;$$
$$A = B = 0.325029\, Ea^2;$$
$$C = 0.326094\, Ea^2;$$

where E is the mass of the Earth and a its equatorial semidiameter.

TABLE 87. — Length of Degrees on the Earth's Surface.

At Lat.	Miles per degree		Km. per degree		At Lat.	Miles per degree		Km. per degree	
	of Long.	of Lat.	of Long.	of Lat.		of Long.	of Lat.	of Long.	of Lat.
0°	69.17	68.70	111.32	110.57	55°	39.77	69.17	64.00	111.33
10	68.13	68.72	109.64	110.60	60	34.67	69.23	55.80	111.42
20	65.03	68.79	104.65	110.70	65	29.32	69.28	47.18	111.50
30	59.96	68.88	96.49	110.85	70	23.73	69.32	38.19	111.57
40	53.06	68.99	85.40	111.03	75	17.96	69.36	28.90	111.62
45	49.00	69.05	78.85	111.13	80	12.05	69.39	19.39	111.67
50	44.55	69.11	71.70	111.23	90	0.00	69.41	0.00	111.70

For more complete table see "Smithsonian Geographical Tables."

TABLE 88.
MISCELLANEOUS ASTRONOMICAL DATA.

Length of sidereal year = 365.2563578 mean solar days;
= 365 days 6 hours 9 minutes 9.314 seconds.

Length of tropical year $= 365.242199870 - 0.0000062124 \frac{t-1850}{100}$ mean solar days;

= 365 days 5 hours 48 minutes $\left(46.069 - 0.53675 \frac{t-1850}{100}\right)$ seconds.

Length of sidereal month

$= 27.321661162 - 0.00000026240 \frac{t-1800}{100}$ days;

= 27 days 7 hours 43 minutes $\left(11.524 - 0.022671 \frac{t-1800}{100}\right)$ seconds.

Length of synodical month

$= 29.5305888435 - 0.00000030696 \frac{t-1800}{100}$ days;

= 29 days 12 hours 44 minutes $\left(2.841 - 0.026522 \frac{t-1800}{100}\right)$ seconds.

Length of sidereal day = 86164.09965 mean solar seconds.

N. B.—The factor containing t in the above equations (the year at which the values of the quantities are required) may in all ordinary cases be neglected.

Mean distance from earth to sun = 92900000 miles = 149500000 kilometers.
Eccentricity of the earth's orbit $= e =$

$$0.01675104 - 0.0000004180\,(t-1900) - 0.000000126\left(\frac{t-1900}{100}\right)^2.$$

Solar parallax = 8.7997″ ± 0.003 (Weinberg, A. N. 165, 1904);
8.807 ± 0.0027 (Hinks, Eros, 7);
8.799 (Samson, Jupiter satellites; Harvard observations).
Lunar parallax = 3422.68″.
Mean distance from earth to moon = 60.2669 terrestrial radii;
= 238854 miles;
= 384393 kilometers.
Lunar inequality of the earth $= L =$ 6.454″.
Parallactic inequality of the moon $= Q =$ 124.80″.
Mean motion of moon's node in 365.25 days $= \mu = -19° 21' 19.6191'' + 0.14136'' \left(\frac{t-1800}{100}\right)$
Eccentricity and inclination of the moon's orbit $= e_2$ = 0.05490807.
Delaunay's $\gamma = \sin \frac{1}{2} I =$ 0.044886793.
$I = 5° 08' 43.3546''$.
Constant of nutation = 9.2′.
Constant of aberration = 20.4962 ± 0.006 (Weinberg, l. c.).*
Time taken by light to traverse the mean radius of the earth's orbit
= 498.82 ± 0.1 seconds (Weinberg);
= 498.64 (Samson).
Velocity of light = 186330 miles per second (Weinberg);
= 299870 ± 0.03 kilometers per second.
General precession = 50.2564″ + 0.000222 (t − 1900).
Obliquity of the ecliptic = 23° 27′ 8.26″ − 0.4684 (t − 1900).
Gravitation constant $= 666.07 \times 10^{-10}$ cm^3/gr. sec$^2 \pm 0.16 \times 10^{-10}$.

* Recent work of Doolittle's and others indicates a value not less than 20.51.

Table 89.—Planetary Data.

Body.	Reciprocals of masses.	Mean distance from the sun. Km.	Sidereal period. Mean days	Equatorial diameter. Km.	Inclination of orbit.	Mean density. $H_2O=1$	Gravity at surface.
Sun	1.	—	—	1391067	—	1.39	27.6
Mercury	6000000.	58 x 10^6	87.97	4842	7°.003	4.86	.3
Venus	408000.	108 "	224.70	12394	3.393	5.2	7.9
Earth*	329390.	149 "	365.26	12756	—	5.52	1.00
Mars	3093500.	228 "	686.98	7320	1.850	3.90	.4
Jupiter	1047.35	778 "	4332.59	145250	1.308	1.36	2.6
Saturn	3501.6	1426 "	10759.20	123040	2.492	.63	1.01
Uranus	22869.	2869 "	30586.29	48590	0.773	1.34	.95
Neptune	19700.	4495 "	60188.71	56040	1.778	1.28	.97
Moon	† 81.45	38 x 10^4	27.32	3473	5.147	3.37	.17

* Earth and moon. † Relative to earth. Inclination of axes: Sun 7°.25; Earth 23°.45; Mars 24°.6; Jupiter 3°.1; Saturn 26°.8; Neptune 27°.2. Others doubtful.

Table 90.—Equation of Time.

The equation of time when + is to be added to the apparent solar time to give mean time. When the place is not on a standard meridian (75'th, etc.) its difference in longitude in time from that meridian must be subtracted when east, added when west to get standard time (75'th meridian time, etc.). The equation varies from year to year cyclically, and the figure following the ± sign gives a rough idea of this variation.

	M. S.		M. S.		M. S.		M. S.
Jan. 1	+ 3 26±14	Apr. 1	+4 2± 7	July 1	+3 31±5	Oct. 1	—10 12± 8
15	+ 9 25± 9	15	+0 8± 5	15	+5 42±3	15	—14 5± 6
Feb. 1	+13 42± 4	May 1	—2 54±10	Aug. 1	+6 9±3	Nov. 1	—16 19± 2
15	+14 20± 2	15	—3 49± 1	15	+4 24±5	15	—15 22± 4
Mar. 1	+12 34± 4	June 1	—2 28± 3	Sept. 1	+0 2±7	Dec. 1	—10 58± 8
15	+ 9 9± 6	15	+0 8± 4	15	—4 41±9	15	— 4 53±10

Table 91.—Miscellaneous Astronomical Data.

Apex of Solar Motion:

From proper motions, R. $A._{1810}$ = 17 51^m, $Dec._{1810}$ = + 31.4 (Weersma, Gron. Publ. 21.)
From radial velocities, R. $A._{1900}$ = $17^h 54^m$, $Dec._{1900}$ = + 25.1 (Campbell, Lick. Bull. 196.)
Velocity = 19.5 Km. per sec. (Campbell.)

Nearest star so far as known: α Centauri, parallax = 0.759″ (Gron. Publ. 24) distance = 4.3 light years.

Stars of both greatest proper motion and greatest radial velocity so far as known:* Cordova, V243; proper motion = 8.70″ in position angle 130° radial velocity + 242 Km. per sec. (Campbell, Stellar Motions, 1913). Parallax = 0.319″ (Gron. Publ. 24, also proper motion). Distance = 10.2 light years.

Average velocities with regard to center of gravity of the stellar system, according to Campbell (Stellar Motion, 1913):

Type B Stars:	6.6 Km. per sec.	Type G Stars:	15.0 Km. per sec.
" A "	10.9 " " "	" K "	16.8 " " "
" F "	14.4 " " "	" M "	17.1 " " "

Sun's magnitude = — 26.5, sending the earth 90,000,000,000 times as much light as the star Aldebaran.

Ratio of total radiation of sun to that of moon about 100,000 to 1 } Langley.
" " " light " " " " " " " 400,000 to 1 } Langley.

* Lalande, 1966, $R.A._{1910}$ $1^h 3^m.9$, $Dec._{1910}$ 61°.4′ in 1913 was found to have a radial velocity (of approach) of 326 Km. per sec. (Mount Wilson Solar Observatory.)

TERRESTRIAL MAGNETISM.

Secular Change of Declination.

Changes in the magnetic declination between 1810, the date of the earliest available observations, and 1910, for one or more places in each state and territory.

State.	Station.	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910
		°	°	°	°	°	°	°	°	°	°	°
Ala.	Montgomery	5.6E	5.8E	5.8E	5.6E	5.4E	5.0E	4.5E	3.9E	3.2E	2.8E	2.9E
Alas.	Sitka	–	–	–		–	28.7E	29.0E	29.3E	29.5E	29.7E	30.2E
	Kodiak	–	–	–	–	–	26.1E	25.6E	25.1E	24.7E	24.4E	24.1E
	Unalaska	–	–	–	–	–	20.4E	20.1E	19.6E	19.0E	18.3E	17.5E
	St. Michael	–	–	–	–	–	–	–	24.7E	23.1E	22.1E	21.4E
Ariz.	Holbrook	–	–		–	13.6E	13.7E	13.8E	13.7E	13.4E	13.5E	13.9E
	Prescott	–	–	–	–	13.3E	13.5E	13.7E	13.6E	13.5E	13.7E	14.3E
Ark.	Little Rock	8.6E	8.8E	9.0E	9.0E	8.8E	8.6E	8.2E	7.6E	7.0E	6.6E.	6.9E
Cal.	Los Angeles	12.1E	12.6E	13.2E	13.6E	14.0E	14.2E	14.4E	14.6E	14.6E	14.9E	15.5E
	San José	15.0E	15.5E	16.0E	16.4E	16.8E	17.1E	17.3E	17.5E	17.5E	17.8E	18.5E
Cal.	Redding	15.6E	16.1E	16.6E	17.0E	17.4E	17.8E	18.1E	18.2E	18.3E	18.6E	19.3E
Colo.	Pueblo	–	–	–	–	13.8E	13.8E	13.8E	13.5E	13.0E	12.9E	13.3E
	Glenwood Sp.	–		–	–	16.1E	16.2E	16.3E	16.1E	15.7E	15.6E	16.1E
Conn.	Hartford	5.1W	5.6W	6.1W	6.8W	7.5W	8.2W	8.7W	9.4W	9.8W	10.4W	11.0W
Del.	Dover	1.6W	1.9W	2.3W	2.8W	3.4W	4.0W	4.7W	5.3W	5.9W	6.4W	7.0W
D. C.	Washington	0.5E	0.3E	0.0	0.5W	1.0W	1.7W	2.4W	3.0W	3.6W	4.2W	4.7W
Fla.	Jacksonville	5.1E	5.1E	4.9E	4.6E	4.2E	3.7E	3.1E	2.4E	1.8E	1.3E	1.2E
	Pensacola	7.7E	7.8E	7.7E	7.5E	7.2E	6.8E	6.2E	5.6E	5.0E	4.5E	4.4E
	Tampa	6.4E	6.2E	5.9E	5.5E	5.0E	4.5E	3.9E	3.3E	2.8E	2.3E	2.0E
Ga.	Macon	5.9E	5.9E	5.7E	5.4E	5.0E	4.5E	3.9E	3.2E	2.6E	2.1E	2.0E
Haw.	Honolulu	–	–		–	9.4E	9.4E	9.5E	9.8E	10.1E	10.4E	10.6E
Idabo	Pocatello	–	–	–	–	17.4E	17.7E	17.8E	17.9E	17.7E	17.8E	18.4E
	Boise	–	–	–	–	18.0E	18.4E	18.6E	18.7E	18.6E	18.8E	19.4E
Ill.	Bloomington	6.3E	6.5E	6.6E	6.5E	6.3E	5.9E	5.4E	4.7E	4.1E	3.6E	3.4E
Ind.	Indianapolis	5.0E	5.1E	5.0E	4.7E	4.4E	3.8E	3.2E	2.6E	2.0E	1.4E	1.1E
Ia.	Des Moines	–	10.2E	10.4E	10.5E	10.4E	10.2E	9.7E	9.1E	8.4E	7.9E	8.1E
Kans.	Emporia	–	–	–	–	11.6E	11.5E	11.2E	10.7E	10.1E	9.8E	10.1E
	Ness City	–	–	–	–	12.4E	12.4E	12.2E	11.9E	11.4E	11.1E	11.4E
Ky.	Lexington	4.5E	4.5E	4.4E	4.1E	3.6E	3.1E	2.5E	1.9E	1.2E	0.7E	0.5E
	Princeton	6.8E	7.0E	7.0E	6.8E	6.5E	6.1E	5.6E	5.0E	4.3E	3.8E	3.7E
La.	Alexandria	8.4E	8.7E	8.8E	8.8E	8.7E	8.4E	8.0E	7.4E	6.9E	6.6E	6.8E
Me.	Eastport	13.6W	14.4W	15.2W	16.0W	17.0W	17.7W	18.2W	18.6W	18.7W	19.0W	19.4W
	Portland	9.0W	9.6W	10.3W	11.0W	11.6W	12.3W	12.8W	13.4W	13.9W	14.4W	14.8W
Md.	Baltimore	0.9W	1.1W	1.4W	1.9W	2.4W	3.1W	3.8W	4.4W	5.0W	5.6W	6.1W
Mass.	Boston	7.3W	7.8W	8.4W	9.1W	9.8W	10.5W	11.0W	11.5W	12.0W	12.6W	13.1W
Mass.	Pittsfield	5.7W	6.1W	6.7W	7.4W	8.1W	8.7W	9.3W	10.0W	10.4W	11.0W	11.5W
Mich.	Marquette	–	6.7E	6.7E	6.5E	6.0E	5.4E	4.6E	3.8E	3.0E	2.3E	2.0E
	Lansing	–	4.2E	4.1E	3.8E	3.3E	2.8E	2.1E	1.3E	0.5E	0.0E	0.4E
Minn.	Northome	–	10.4E	10.7E	10.8E	10.7E	10.4E	10.0E	9.3E	8.6E	8.0E	8.1E
	Mankato	–	11.3E	11.6E	11.7E	11.6E	11.3E	10.9E	10.4E	9.5E	9.0E	9.1E

* Tables have been compiled from United States Magnetic Tables and Magnetic Charts for 1905, published by the Coast and Geodetic Survey in 1908.

TERRESTRIAL MAGNETISM (continued).

Secular Change of Declination (continued).

State.	Station.	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900	1910
		°	°	°	°	°	°	°	°	°	°	°
Miss.	Jackson	8.2E	8.4E	8.5E	8.4E	8.2E	7.9E	7.5E	6.9E	6.4E	6.0E	6.2E
Mo.	Sedalia	–	10.0E	10.2E	10.2E	10.1E	9.8E	9.4E	8.7E	8.0E	7.6E	7.9E
Mont.	Forsyth	–	–	–	18.2E	18.5E	18.6E	18.6E	18.4E	17.9E	17.8E	18.3E
	Helena	–	–	–	18.9E	19.3E	19.6E	19.8E	19.6E	19.4E	19.5E	20.0E
Nebr.	Hastings	–	11.6E	12.0E	12.1E	12.1E	12.0E	11.7E	11.2E	10.5E	10.2E	10.5E
Nebr.	Alliance	–	–	–	–	15.4E	15.4E	15.3E	14.8E	14.3E	14.2E	14.5E
Nev.	Elko	–	–	–	–	17.3E	17.6E	17.7E	17.7E	17.6E	17.8E	18.3E
	Hawthorne	–	–	–	–	16.3E	16.6E	16.9E	17.0E	17.0E	17.3E	17.8E
N. H.	Hanover	7.1W	7.5W	8.2W	8.9W	9.8W	10.5W	11.1W	11.6W	12.0W	12.5W	13.0W
N. J.	Trenton	2.8W	3.1W	3.5W	4.1W	4.7W	5.4W	6.0W	6.7W	7.2W	7.8W	8.4W
N. M.	Santa Rosa	–	–	–	–	12.7E	12.8E	12.7E	12.5E	12.1E	12.0E	12.4E
	Laguna	–	–	–	–	13.4E	13.6E	13.6E	13.4E	13.0E	13.0E	13.5E
N. Y.	Albany	5.6W	5.8W	6.3W	6.9W	7.6W	8.4W	9.1W	9.8W	10.2W	10.8W	11.4W
	Elmira	2.2W	2.4W	2.8W	3.3W	4.0W	4.8W	5.4W	6.3W	7.0W	7.6W	8.1W
N. C.	Newbern	1.7E	1.6E	1.3E	0.8E	0.3E	0.3W	1.0W	1.6W	2.2W	2.8W	3.3W
N. C.	Salisbury	3.9E	3.8E	3.6E	3.2E	2.7E	2.1E	1.5E	0.8E	0.2E	0.4W	0.7W
N. Dak.	Jamestown	–		–	–	14.5E	14.3E	14.0E	13.5E	12.7E	12.4E	12.8E
	Dickinson	–	–	–	–	17.6E	17.6E	17.4E	17.0E	16.4E	16.2E	16.6E
Ohio	Columbus	3.4E	3.4E	3.2E	2.9E	2.4E	1.8E	1.2E	0.6E	0.0	0.7W	1.1W
Okla.	Okmulgee	–	–	–	–	10.2E	10.1E	9.8E	9.4E	8.8E	8.5E	8.9E
Okla.	Enid	–	–	–	–	11.2E	11.1E	10.9E	10.5E	9.9E	9.7E	10.1E
Oreg.	Sumpter	–	–	–	–	19.3E	19.7E	20.0E	20.2E	20.2E	20.4E	21.0E
	Detroit	16.7E	17.4E	18.0E	18.6E	19.2E	19.7E	20.1E	20.4E	20.5E	20.8E	21.5E
Pa.	Philadelphia	2.2W	2.4W	2.8W	3.4W	4.1W	4.8W	5.5W	6.3W	6.8W	7.4W	8.0W
	Altoona	0.5W	0.6W	0.9W	1.3W	1.8W	2.4W	3.1W	3.8W	4.5W	5.1W	5.6W
P. R.	San Juan	–	–	–	–		–	–	–	–	1.0W	2.0W
R. I.	Newport	6.6W	7.1W	7.7W	8.4W	9.1W	9.8W	10.3W	10.8W	11.3W	11.9W	12.4W
S. C.	Columbia	4.4E	4.3E	4.1E	3.7E	3.2E	2.7E	2.1E	1.4E	0.8E	0.2E	0.1W
S. D.	Huron		–	–	13.1E	13.1E	12.9E	12.6E	12.1E	11.4E	11.1E	11.4E
	Rapid City		–	–	–	16.4E	16.4E	16.3E	15.8E	15.3E	15.1E	15.4E
Tenn.	Chattanooga	5.3E	5.3E	5.1E	4.8E	4.4E	3.9E	3.3E	2.6E	2.0E	1.5E	1.3E
	Huntington	–	7.4E	7.4E	7.3E	7.0E	6.6E	6.1E	5.5E	4.9E	4.4E	4.3E
Tex.	Houston	–	8.9E	9.2E	9.3E	9.3E	9.2E	8.9E	8.5E	7.9E	7.7E	8.1E
	San Antonio	–	–	9.6E	9.8E	9.9E	9.8E	9.6E	9.3E	8.9E	8.7E	9.1E
	Pecos	–	–	10.8E	11.0E	11.1E	11.1E	11.0E	10.8E	10.4E	10.3E	10.7E
Tex.	Floydada	–	–	–	–	11.3E	11.3E	11.2E	10.9E	10.4E	10.3E	10.7E
Utah	Salt Lake	–	–	–	–	16.4E	16.6E	16.7E	16.5E	16.3E	16.5E	17.0E
Vt.	Rutland	6.8W	7.2W	7.8W	8.5W	9.2W	10.0W	10.6W	11.2W	11.6W	12.1W	12.7W
Va.	Richmond	0.8E	0.6E	0.3W	0.1W	0.6W	1.2W	1.8W	2.5W	3.1W	3.7W	4.2W
	Lynchburg	1.9E	1.8E	1.6E	1.2E	0.8E	0.2E	0.5W	1.2W	1.8W	2.4W	2.8W
Wash.	Wilson Creek					21.3E	21.6E	21.9E	21.9E	22.1E	22.4E	22.9E
	Seattle	19.1E	19.7E	20.3E	20.8E	21.3E	21.8E	22.1E	22.3E	22.6E	23.0E	23.5E
W. Va.	Charleston	2.3E	2.2E	2.0E	1.6E	1.1E	0.5E	0.2W	0.9W	1.5W	2.1W	2.6W
Wis.	Madison	–	8.6E	8.7E	8.6E	8.3E	7.8E	7.2E	6.4E	5.6E	5.0E	4.9E
Wyo.	Douglas	–	–	–	–	15.8E	16.0E	16.0E	15.8E	15.4E	15.3E	15.7E
	Green River	–	–	–	–	16.8E	17.0E	17.0E	16.9E	16.6E	16.6E	17.0E

TERRESTRIAL MAGNETISM (*continued*).

TABLE 93. — Dip or Inclination.

This table gives for the epoch January 1, 1905, the values of the magnetic dip, I, corresponding to the longitudes west of Greenwich in the heading and the north latitudes in the first column.

	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
°	°	°	°	°	°	°	°	°	°	°	°	°	°
19	-	-	48.8	49.1	47.5	46.3	44.8	44.2	43.9	-	-		-
21	-	-	51.0	51.1	50.0	49.3	48.2	47.0	46.5	-	-		-
23	-	-	53.7	53.0	52.4	51.8	50.7	49.6	48.8	48.2	-	-	-
25	-	-	56.3	56.0	55.0	54.5	53.2	52.4	51.5	50.6	49.8	48.3	-
27	-	-	58.9	58.1	57.6	56.8	55.6	54.7	53.9	53.1	52.6	51.0	-
29	-	60.7	61.0	60.2	59.8	58.9	58.2	57.2	56.2	55.5	54.8	53.7	-
31	-	63.0	63.1	62.6	62.0	61.3	60.6	59.6	58.7	57.7	56.7	56.0	-
33	-	65.0	65.0	64.6	64.0	63.5	62.7	62.0	61.0	59.8	58.9	58.1	-
35	-	67.0	66.9	66.5	66.0	65.6	64.9	63.7	62.7	62.3	61.0	60.2	-
37	-	68.6	68.9	68.6	68.2	67.7	66.9	66.2	65.1	64.6	62.9	62.2	-
39	-	70.3	70.6	70.4	70.2	69.7	68.8	68.1	67.2	66.1	65.0	64.0	62.8
41	-	71.8	72.2	72.2	71.9	71.4	70.8	69.8	68.9	67.8	66.8	65.6	64.7
43	-	73.5	73.9	74.1	73.8	73.3	72.6	71.6	70.7	69.6	68.6	67.5	66.3
45	74.4	74.8	75.6	75.5	75.4	75.0	74.3	73.6	72.4	71.5	70.3	69.2	68.1
47	75.7	76.2	76.9	76.8	76.9	76.8	76.0	75.2	74.2	73.0	71.8	70.8	69.9
49	76.8	78.1	78.2	78.3	78.7	78.1	77.5	76.8	75.8	74.5	73.5	72.3	71.4

TABLE 94. — Secular Change of Dip.

Values of magnetic dip for places designated by the north latitudes and longitudes west of Greenwich in the first two columns for January 1st of the years in the heading. The degrees are given in the third column and minutes in the succeeding columns.

Latitude.	Longitude.		1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
°	°	°	′	′	′	′	′	′	′	′	′	′	′	′
25	80	55+	49	49	48	46	43	40	35	35	39	48	60	77
25	110	49+	08	20	30	39	46	55	61	68	76	86	96	106
30	83	60+	66	70	73	74	73	67	57	51	53	63	78	96
30	100	57+	44	49	58	67	70	65	60	61	68	77	90	105
30	115	54+	53	62	69	71	70	72	75	79	85	91	96	101
35	80	66+	57	58	57	54	45	35	26	21	20	22	30	38
35	90	65+	65	59	51	44	37	32	26	25	25	27	36	48
35	105	62+	-	-	-	32	30	24	24	24	28	34	42	50
35	120	60+	03	06	08	08	07	06	08	11	13	14	12	08
40	75	71+	82	82	78	73	65	55	43	33	27	24	24	24
40	90	70+	30	31	34	37	36	32	29	26	25	26	30	36
40	105	67+	-	-	-	56	53	51	51	51	52	56	60	65
40	120	64+	-	48	46	44	44	44	44	44	45	45	48	48
45	65	74+	116	110	101	92	80	68	57	46	35	28	24	20
45	75	75+	103	99	95	90	85	73	62	53	43	38	36	34
45	90	74+	81	81	81	79	77	75	68	63	61	59	60	60
45	105	72+	-	-	-	-	-	22	20	20	21	22	24	27
45	122.5	68+	35	34	37	40	40	39	37	34	30	26	24	20
49	92	78+	26	25	24	22	20	20	15	12	11	09	06	04
49	120	72+	-	26	24	22	22	19	20	19	19	19	18	16

TERRESTRIAL MAGNETISM (*continued*).

TABLE 95.—Horizontal Intensity.

This table gives for the epoch January 1, 1905, the horizontal intensity, H, expressed in C. G. S. units, corresponding to the longitudes in the heading and the latitudes in the first column.

°	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
19	–	–	.307	.314	.319	.322	.328	.332	.331				
21	–	–	.301	.309	.314	.316	.320	.324	.324				
23	–	–	.293	.303	.305	.309	.312	.315	.317	.320			
25	–	–	.284	.292	.295	.299	.304	.307	.308	.309	.312	.304	
27	–	–	.274	.280	.286	.289	.296	.298	.300	.303	.306	.298	
29	–	.257	.262	.269	.276	.281	.286	.289	.292	.294	.297	.291	
31	–	.246	.251	.256	.263	.269	.274	.277	.282	.284	.285	.282	
33	–	.233	.239	.245	.251	.257	.262	.266	.270	.273	.274	.274	
35	–	.220	.225	.232	.240	.242	.248	.253	.256	.259	.262	.265	
37	–	.208	.209	.218	.222	.226	.232	.238	.245	.246	.252	.251	
39	–	.197	.198	.203	.206	.212	.217	.224	.229	.237	.240	.242	.245
41	–	.184	.185	.186	.192	.196	.202	.207	.216	.223	.228	.240	.236
43	–	.170	.170	.169	.175	.178	.187	.194	.201	.210	.215	.222	.226
45	.161	.157	.155	.156	.157	.162	.169	.177	.190	.192	.199	.208	.215
47	.145	.144	.140	.142	.142	.150	.152	.161	.170	.180	.188	.196	.201
49	.131	.129	.125	.126	.124	.129	.138	.146	.153	.165	.175	.182	.187

TABLE 96.—Secular Change of Horizontal Intensity.

Values of horizontal intensity in C. G. S. units for places designated by the latitude and longitude in the first two columns for January 1 of the years in the heading.

Latitude. °	Longitude. °	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
25	80	.3099	.3086	.3073	.3057	.3042	.3025	.3008	.2990	.2970	.2949	.2920	.2890
25	110	.3229	.3218	.3204	.3189	.3170	.3155	.3143	.3130	.3117	.3104	.3090	.3075
30	83	.2803	.2795	.2788	.2780	.2772	.2763	.2752	.2740	.2725	.2706	.2680	.2644
30	100	–	–	.2961	.2942	.2924	.2907	.2891	.2877	.2865	.2850	.2830	.2804
30	115	.3040	.3026	.3011	.2996	.2979	.2964	.2952	.2940	.2929	.2920	.2910	.2898
35	80	.2384	.2379	.2374	.2369	.2367	.2363	.2359	.2352	.2347	.2337	.2320	.2296
35	90	–	–	–	.2462	.2462	.2461	.2458	.2455	.2447	.2437	.2430	.2399
35	105	–	–	–	–	.2620	.2608	.2599	.2590	.2583	.2573	.2560	.2544
35	120	–	–	–	.2720	.2707	.2695	.2683	.2672	.2663	.2656	.2650	.2644
40	75	.1880	.1883	.1891	.1902	.1911	.1919	.1925	.1930	.1931	.1928	.1920	.1909
40	90	–	.2086	.2082	.2079	.2076	.2075	.2074	.2072	.2068	.2060	.2050	.2036
40	105	–		–	.2272	.2266	.2261	.2257	.2253	.2248	.2240	.2230	.2217
40	120	–		–	.2429	.2420	.2412	.2406	.2399	.2392	.2386	.2380	.2379
45	65	.1504	.1514	.1525	.1537	.1553	.1567	.1578	.1589	.1600	.1608	.1610	.1610
45	75	.1483	.1485	.1488	.1495	.1506	.1516	.1527	.1538	.1546	.1550	.1550	.1554
45	90	–	.1635	.1633	.1631	.1628	.1626	.1624	.1623	.1624	.1623	.1620	.1616
45	105	–	–	–	.1920	.1919	.1918	.1916	.1913	.1910	.1906	.1900	.1892
45	122.5	.2175	.2170	.2162	.2153	.2145	.2135	2127	.2121	.2117	.2115	.2115	.2115
49	92	.1332	.1330	.1328	.1324	.1321	.1319	.1318	.1318	.1321	.1324	.1330	.1335
49	120	.1841	.1841	.1840	.1839	.1836	.1831	.1826	.1821	.1819	.1820	.1820	.1824

TERRESTRIAL MAGNETISM (*continued*).

TABLE 97. — Total Intensity.

This table gives for the epoch January 1, 1905, the values of total intensity, F, expressed in C. G. S. units corresponding to the longitudes in the heading and the latitudes in the first column.

°	65°	70°	75°	80°	85°	90°	95°	100°	105°	110°	115°	120°	125°
19	–	–	.466	.480	.472	.466	.462	.463	.459		–	–	–
21	–	–	.478	.492	.489	.485	.480	.475	.471	–	–		–
23	–	–	.495	.504	.500	.500	.493	.486	.481	.480	–		–
25	–	–	.512	.522	.514	.515	.507	.503	.495	.487	.483	.457	–
27	–	–	.530	.530	.534	.528	.524	.516	.509	.505	.504	.474	–
29	–	.525	.540	.541	.549	.544	.543	.534	.525	.519	.515	.492	–
31	–	.542	.555	.556	.560	.560	.558	.547	.543	.531	.519	.504	–
33	–	.551	.566	.571	.572	.576	.571	.567	.557	.543	.530	.518	–
35	–	.563	.574	.582	.590	.586	.584	.571	.558	.557	.540	.533	–
37	–	.570	.581	.598	.598	.596	.591	.590	.582	.573	.553	.538	–
39	–	.584	.596	.605	.608	.611	.600	.600	.591	.585	.568	.552	.536
41	–	.589	.605	.608	.618	.614	.614	.600	.600	.590	.579	.581	.552
43	–	.599	.613	.617	.627	.619	.625	.614	.608	.602	.589	.580	.562
45	.599	.599	.623	.623	.623	.626	.624	.627	.628	.605	.590	.586	.576
47	.587	.604	.618	.622	.626	.657	.628	.630	.624	.616	.602	.596	.585
49	.574	.626	.611	.621	.633	.626	.638	.639	.624	.617	.616	.599	.588

TABLE 98. — Secular Change of Total Intensity.

Values of total intensity in C. G. S. units for places designated by the latitudes and longitudes in the first two columns for January 1 of the years in the heading. (Computed from Tables 92 and 94.)

Latitude	Longitude.	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
°	°												
25	80	.5516	.5493	.5467	.5434	.5400	.5364	.5322	.5290	.5264	.5247	.5222	.5206
25	110	.4935	.4938	.4933	.4925	.4908	.4902	.4891	.4883	.4876	.4873	.4868	.4860
30	83	.5800	.5796	.5790	.5777	.5757	.5720	.5668	.5625	.5600	.5590	.5581	.5559
30	100	–	–	.5583	.5570	.5544	.5499	.5456	.5432	.5427	.5421	.5416	.5405
30	115	.5285	.5280	.5269	.5247	.5215	.5194	.5179	.5167	.5160	.5158	.5151	.5140
35	80	.6089	.6080	.6063	.6038	.5996	.5946	.5900	.5863	.5874	.5830	.5818	.5789
35	90	–	–	–	.5991	.5964	.5942	.5912	.5901	.5882	.5865	.5858	.5852
35	105	–	–	–	–	.5674	.5629	.5610	.5590	.5588	.5585	.5582	.5572
35	120	–	–	–	.5462	.5433	.5406	.5388	.5374	.5361	.5350	.5332	.5309
40	75	.6206	.6216	6220	.6227	.6212	.6182	.6136	.6098	.6070	.6045	.6019	.5985
40	90	–	.6254	.6258	.6264	.6250	.6226	.6208	.6187	.6170	.6151	.6141	.6135
40	105	–	–	–	.6048	.6019	.5997	.5986	.5976	.5967	.5963	.5953	.5940
40	120	–	–	–	.5691	.5670	.5651	.5637	.5620	.5608	.5593	.5590	.5591
45	65	.6188	.6186	.6167	.6152	.6134	.6107	.6077	.6048	.6019	.6005	.5987	.5962
45	75	.6454	.6431	.6413	.6404	.6412	.6363	.6327	.6306	.6266	.6247	.6233	.6235
45	90	–	.6465	.6457	.6434	.6408	.6386	.6330	.6291	.6382	.6264	.6259	.6244
45	105	–	–	–	–	–	.6332	.6314	.6303	.6299	.6392	.6284	.6275
45	122.5	.5956	.5938	.5930	.5918	.5896	.5864	.5834	.5804	.5776	.5754	.5745	.5728
49	92	.6643	.6624	.6604	.6566	.6533	.6523	.6472	.6445	.6451	.6447	.6450	.6456
49	120	–	.6100	.6085	.6071	.6061	.6028	.6017	.5995	.5988	.5992	.5986	.5988

Table 99.

AGONIC LINE.

The line of no declination appears to be still moving westward in the United States, but the line of no annual change is only a short distance to the west of it, so that it is probable that the extreme westerly position will soon be reached.

Lat. N.	Longitudes of the agonic line for the years—				
	1800	1850	1875	1890	1905
°	°	°	°	°	°
25	-	-	-	75.5	76.1
30	-	-	-	78.6	79.7
35	-	76.7	79.0	79.9	81.7
6	75.2	77.3	79.7	80.5	82.8
7	76.3	77.7	80.6	82.2	83.5
8	76.7	78.3	81.3	82.6	83.6
9	76.9	78.7	81.6	82.2	83.6
40	77.0	79.3	81.6	82.7	84.0
1	77.9	80.4	81.8	82.8	84.6
2	79.1	81.0	82.6	83.7	84.8
3	79.4	81.2	83.1	84.3	85.0
4	79.8	-	83.3	84.9	85.5
45	-	-	83.6	85.2	86.0
6	-	-	84.2	84.8	86.4
7	-	-	85.1	85.4	86.4
8	-	-	86.0	85.9	86.5
9	-	-	86.5	86.3	87.2

TABLE 100.

RECENT VALUES OF THE MAGNETIC ELEMENTS AT MAGNETIC OBSERVATORIES.

(Compiled by the Department of Terrestrial Magnetism, Carnegie Institution of Washington.)

Place.	Latitude.	Longitude.	Middle of year.	Magnetic Elements. Declination.	Inclination.	Intensity (C.G.S. units). Hor'l.	Ver'l.	Total.
	° ′	° ′		° ′	° ′			
Pawlowsk	59 41N	30 29E	1907	1 09.9E	70 37.7N	.1650	.4694	.4975
Sitka	57 03N	135 20W	1910	30 16.4E	74 32.2N	.1559	.5637	.5849
Katharinenburg	57 03N	60 38E	1907	10 35.5E	70 52.2N	.1762	.5081	.5378
Rude Skov	55 51N	12 27E	1910	9 28.7W	68 45.0N	.1738	.4468	.4794
Eskdalemuir	55 19N	3 12W	1911	18 12.4W	69 37.1N	.1685	.4534	.4837
Stonyhurst	53 51N	2 28W	1912	17 03.6W	68 41.4N	.1740	.4460	.4787
Wilhelmshaven	53 32N	8 09E	1910	11 37.0W	67 30.5N	.1812	.4377	.4737
Potsdam	52 23N	13 04E	1912	8 45.9W	66 20.4N	.1880	.4291	.4685
Seddin	52 17N	13 01E	1912	8 47.2W	66 17.4N	.1884	.4290	.4685
Irkutsk	52 16N	104 16E	1905	1 58.1E	70 25.0N	.2001	.5625	.5970
De Bilt	52 06N	5 11E	1910	12 58.2W	66 46.5N	.1854	.4321	.4702
Valencia	51 56N	10 15W	1911	20 38.1W	68 12.1N	.1789	.4473	.4817
Clausthal	51 48N	10 20E	1905	10 40.3W	....	...	...	...
Bochum	51 29N	7 14E	1911	11 48.3W	....	...	...	...
Kew	51 28N	0 19W	1911	15 55.3W	66 57.2N	.1850	.4349	.4726
Greenwich	51 28N	0 00	1911	15 33.0W	66 52.1N	.1852	.4337	.4716
Uccle	50 48N	4 21E	1911	13 13.9W	66 00.1N	.1902	.4273	.4677
Hermsdorf	50 46N	16 14E	1912	7 06.9W	....	...	...	...
Beuthen	50 21N	18 55E	1908	6 12.3W	....	...	...	...
Falmouth	50 09N	5 05W	1912	17 24.2W	66 26.6N	.1880	.4312	.4704
Prague	50 05N	14 25E	1910	8 09.6W	....	...	...	...
Cracow	50 04N	19 58E	1911	5 18.1W	64 15.5N	...	...	...
St. Helier (Jersey)	49 12N	2 05W	1907	16 27.4W	65 34.5N	...	...	...
Val Joyeux	48 49N	2 01E	1911	14 17.6W	64 41.6N	.1974	.4176	.4619
Munich	48 09N	11 37E	1910	9 31.5W	63 08.4N	.2064	.4075	.4568
Kremsmünster	48 03N	14 08E	1904	9 02.4W	....	...	...	...
O'Gyalla (Pesth)	47 53N	18 12E	1911	6 25.6W	....	.2107	...	...
Odessa	46 26N	30 46E	1910	3 35.9W	62 26.9N	.2171	.4161	.4693
Pola	44 52N	13 51E	1911	8 17.5W	60 03.6N	.2219	.3853	.4446
Agincourt (Toronto)	43 47N	79 16W	1910	6 03.9W	74 38.5N	.1627	.5923	.6142
Perpignan	42 42N	2 53E	1910	12 44.8W	....	...	...	...
Tiflis	41 43N	44 48E	1905	2 41.6E	56 02.8N	.2545	.3780	.4557
Capodimonte	40 52N	14 15E	1911	....	56 11.7N	...	...	...
Ebro (Tortosa)	40 49N	0 31E	1911	13 18.6W	57 54.8N	.2326	.3709	.4378
Coimbra	40 12N	8 25W	1911	16 27.4W	58 46.4N	.2301	.3795	.4438
Mount Weather	39 04N	77 53W	1908	3 39.2W	....	...	...	...
Baldwin	38 47N	95 10W	1908	8 33.0E	68 47.8N	.2171	.5597	.6003
Cheltenham	38 44N	76 50W	1910	5 41.4W	70 35.4N	.1983	.5626	.5966
Athens	37 59N	23 42E	1908	4 53.0W	52 11.7N	.2620	.3361	.4262
San Fernando	36 28N	6 12W	1911	15 05.2W	54 31.5N	.2489	...	...
Tokio	35 41N	139 45E	1910	4 58.2W	49 07.3N	.3001	.3467	.4585
Tucson	32 15N	110 50W	1910	13 25.8E	59 19.6N	.2741	.4621	.5372
Zi-ka-wei	31 12N	121 26E	1907	2 33.6W	45 36.6N	.3306	.3377	.4726
Dehra Dun	30 19N	78 03E	1910	2 31.9E	43 54.8N	.3326	.3202	.4617
Helwan	29 52N	31 20E	1912	2 25.4W	40 43.7N	.3006	.2588	.3967
Barrackpore	22 46N	88 22E	1910	0 55.5E	30 42.2N	.3733	.2217	.4341
Hongkong	22 18N	114 10E	1910	0 00.4E	30 58.8N	.3711	.2228	.4328
Honolulu	21 19N	158 04W	1910	9 29.7E	39 47.2N	.2916	.2428	.3795
Toungoo	18 56N	96 27E	1910	0 24.9E	23 02.1N	.3880	.1650	.4216
Alibág	18 38N	72 52E	1912	0 51.2E	23 56.1N	.3687	.1637	.4034
Vieques	18 09N	65 26W	1910	2 20.6W	49 52.0N	.2886	.3424	.4478
Antipolo	14 36N	121 10E	1911	0 40.9E	16 18.2N	.3820	.1117	.3981
Kodaikanal	10 14N	77 28E	1910	0 55.0W	3 45.2N	.3748	.0246	.3757
Batavia-Butenzorg	6 11S	106 49E	1909	0 49.5E	31 09.2S	.3668	.2218	.4286
St. Paul de Loanda	8 48S	13 13E	1910	16 12.3W	35 32.2S	.2012	.1437	.2473
Samoa (Apia)	13 48S	171 46W	1908	9 41.9E	29 21.7S	.3561	.2004	.4086
Tananarive	18 55S	47 32E	1907	9 29.7W	54 05.7S	.2533	.3499	.4319
Mauritius	20 06S	57 33E	1911	9 18.5W	53 30.6S	.2331	.3151	.3920
Rio de Janeiro	22 55S	43 11W	1906	8 55.3W	13 57.2S	.2477	.0617	.2553
			1910	9 40.0W	....	...	...	...

PRESSURE OF COLUMNS OF MERCURY AND WATER.

British and metric measures. Correct at 0° C. for mercury and at 4° C. for water.

Metric Measure.			British Measure.		
Cms. of Hg.	Pressure in grams per sq. cm.	Pressure in pounds per sq. inch.	Inches of Hg.	Pressure in grams per sq. cm.	Pressure in pounds per sq. inch.
1	13.5956	0.193376	1	34.533	0.491174
2	27.1912	0.386752	2	69.066	0.982348
3	40.7868	0.580128	3	103.598	1.473522
4	54.3824	0.773504	4	138.131	1.964696
5	67.9780	0.966880	5	172.664	2.455870
6	81.5736	1.160256	6	207.197	2.947044
7	95.1692	1.353632	7	241.730	3.438218
8	108.7648	1.547008	8	276.262	3.929392
9	122.3604	1.740384	9	310.795	4.420566
10	135.9560	1.933760	10	345.328	4.911740
Cms. of H_2O.	Pressure in grams per sq. cm.	Pressure in pounds per sq. inch.	Inches of H_2O.	Pressure in grams per sq. cm.	Pressure in pounds per sq. inch.
1	1	0.0142234	1	2.54	0.036127
2	2	0.0284468	2	5.08	0.072255
3	3	0.0426702	3	7.62	0.108382
4	4	0.0568936	4	10.16	0.144510
5	5	0.0711170	5	12.70	0.180637
6	6	0.0853404	6	15.24	0.216764
7	7	0.0995638	7	17.78	0.252892
8	8	0.1137872	8	20.32	0.289019
9	9	0.1280106	9	22.86	0.325147
10	10	0.1422340	10	25.40	0.361274

REDUCTION OF BAROMETRIC HEIGHT TO STANDARD TEMPERATURE.*

Corrections for brass scale and English measure.		Corrections for brass scale and metric measure.		Corrections for glass scale and metric measure.	
Height of barometer in inches.	a in inches for temp. F.	Height of barometer in mm.	a in mm. for temp. C.	Height of barometer in mm.	a in mm. for temp. C.
15.0	0.00135	**400**	0.0651	**50**	0.0086
16.0	.00145	410	.0668	100	.0172
17.0	.00154	420	.0684	150	.0258
17.5	.00158	430	.0700	200	.0345
18.0	.00163	440	.0716	250	.0431
18.5	.00167	450	.0732	300	.0517
19.0	.00172	460	.0749	350	.0603
19.5	.00176	470	.0765		
		480	.0781	**400**	0.0689
20.0	0.00181	490	.0797	450	.0775
20.5	.00185			500	.0861
21.0	.00190	**500**	0.0813	520	.0895
21.5	.00194	510	.0830	540	.0930
22.0	.00199	520	.0846	560	.0965
22.5	.00203	530	.0862	580	.0999
23.0	.00208	540	.0878		
23.5	.00212	550	.0894	**600**	0.1034
		560	.0911	610	.1051
24.0	0.00217	570	.0927	620	.1068
24.5	.00221	580	.0943	630	.1085
25.0	.00226	590	.0959	640	.1103
25.5	.00231			650	.1120
26.0	.00236	**600**	0.0975	660	.1137
26.5	.00240	610	.0992		
27.0	.00245	620	.1008	**670**	0.1154
27.5	.00249	630	.1024	680	.1172
		640	.1040	690	.1189
28.0	0.00254	650	.1056	700	.1206
28.5	.00258	660	.1073	710	.1223
29.0	.00263	670	.1089	720	.1240
29.2	.00265	680	.1105	730	.1258
29.4	.00267	690	.1121		
29.6	.00268			**740**	0.1275
29.8	.00270	**700**	0.1137	750	.1292
30.0	.00272	710	.1154	760	.1309
		720	.1170	770	.1327
30.2	0.00274	730	.1186	780	.1344
30.4	.00276	740	.1202	790	.1361
30.6	.00277	750	.1218	800	.1378
30.8	.00279	760	.1235		
31.0	.00281	770	.1251	**850**	0.1464
31.2	.00283	780	.1267	900	.1551
31.4	.00285	790	.1283	950	.1639
31.6	.00287	**800**	.1299	1000	.1723

* The height of the barometer is affected by the relative thermal expansion of the mercury and the glass, in the case of instruments graduated on the glass tube, and by the relative expansion of the mercury and the metallic inclosing case, usually of brass, in the case of instruments graduated on the brass case. This relative expansion is practically proportional to the first power of the temperature. The above tables of values of the coefficient of relative expansion will be found to give corrections almost identical with those given in the International Meteorological Tables. The numbers tabulated under a are the values of a in the equation $H_t = H_t' - a(t' - t)$ where H_t is the height at the standard temperature, H_t' the observed height at the temperature t', and $a(t' - t)$ the correction for temperature. The standard temperature is 0° C. for the metric system and 28°.5 F. for the English system. The English barometer is correct for the temperature of melting ice at a temperature of approximately 28°.5 F., because of the fact that the brass scale is graduated so as to be standard at 62° F., while mercury has the standard density at 32° F.

EXAMPLE.—A barometer having a brass scale gave $H = 765$ mm. at 25° C.; required, the corresponding reading at 0° C. Here the value of a is the mean of .1235 and .1251, or .1243; ∴ $a(t' - t) = .1243 \times 25 = 3.11$. Hence $H_0 = 765 - 3.11 = 761.89$.

N. B.—Although a is here given to three and sometimes to four significant figures, it is seldom worth while to use more than the nearest two-figure number. In fact, all barometers have not the same values for a, and when great accuracy is wanted the proper coefficients have to be determined by experiment.

CORRECTION OF BAROMETER TO STANDARD GRAVITY.

Altitude term. Correction is to be subtracted.

Correction in millimeters for elevation above sea level in first column and height of barometer in top line.

Height above sea level in meters.	400	450	500	550	600	650	700	750	800
100							.014	.015	.016
200							.028	.030	.032
300							.041	.044	.047
400							.055	.059	.063
500						.064	.068	.073	.078
600						.077	.082	.088	
700						.090	.096	.102	
800						.103	.109	.117	
900						.115	.123	.131	
1000				.108	.118	.128	.137	.146	
1100				.118	.130	.141	.150		
1200				.129	.142	.154	.164		
1300				.140	.153	.166	.178		
1400				.151	.165	.179	.191		
1500			.147	.162	.176	.191	.205		
1600			.157	.172	.188	.204			
1700			.167	.183	.200	.217			
1800			.177	.194	.212	.230			
1900			.187	.204	.224	.242			
2000		.176	.196	.215	.235	.255			
2100		.185	.206	.226	.247				
2200		.194	.216	.237	.259				
2300		.203	.226	.248	.271				
2400		.212	.236	.259	.283				
2500	.195	.220	.245	.270	.295				
2600	.203	.229	.255						
2700	.211	.238	.265						
2800	.219	.247	.275						
2900	.227	.256	.285						
3000	.235	.265	.294						
3100	.243	.274							
3200	.251	.283							
3300	.259	.292							
3400	.267	.201							
3500	.275	.309							
3600	.283								
3700	.291								
3800	.299								
3900	.307								
4000	.314								

Observed height of barometer in millimeters.

Corrections in hundredths of an inch for elevation above sea level in last column and height of barometer in bottom line.

32	30	28	26	24	22	20	18	16	14	Height above sea level in feet.
									1.255	15000
									1.213	14500
								1.340	1.172	14000
								1.292	1.130	13500
								1.244	1.088	13000
							1.345	1.196	1.046	12500
							1.291	1.149	1.004	12000
							1.237	1.101	.962	11500
						1.315	1.184	1.053	.920	11000
						1.255	1.130	1.005	.879	10500
						1.196	1.076	.957	.837	10000
					1.050	1.136	1.022	.909	.795	9500
					.984	1.076	.969	.861	.753	9000
					.918	1.016	.915	.813		8500
					.853	.957	.861	.765		8000
				1.077	.787	.897	.807			7500
				1.005	.721	.837	.753			7000
				.934	.655	.777	.700			6500
				.862	.789	.718				6000
				.790	.724	.658				5500
			.779	.718	.658	.598				5000
			.701	.646	.592					4500
			.623	.574	.526					4000
			.545	.503	.461					3500
		.503	.467	.431	.395					3000
		.419	.389	.359						2500
	.359	.335	.311	.287						2000
	.269	.251	.233	.215						1500
.192	.179	.167	.155							1000
.096	.090	.084	.078							500

Observed height of barometer in inches.

REDUCTION OF BAROMETER TO STANDARD GRAVITY.*

Reduction to Latitude 45°. — English Scale.

N. B. From latitude 0° to 44° the correction is to be subtracted.
From latitude 90° to 46° the correction is to be added.

Latitude.		Height of the barometer in inches.											
		19	20	21	22	23	24	25	26	27	28	29	30
		Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
0°	90°	0.051	0.053	0.056	0.059	0.061	0.064	0.067	0.069	0.072	0.074	0.077	0.080
5	85	0.050	0.052	0.055	0.058	0.060	0.063	0.066	0.068	0.071	0.073	0.076	0.079
6	84	.049	.052	.055	.057	.060	.062	.065	.068	.070	.073	.076	.078
7	83	.049	.052	.054	.057	.059	.062	.065	.067	.070	.072	.075	.077
8	82	.049	.051	.054	.056	.059	.061	.064	.067	.069	.072	.074	.077
9	81	.048	.051	.053	.056	.058	.061	.063	.066	.068	.071	.073	.076
10	80	0.048	0.050	0.053	0.055	0.058	0.060	0.063	0.065	0.068	0.070	0.073	0.075
11	79	.047	.049	.052	.054	.057	.059	.062	.064	.067	.069	.072	.074
12	78	.046	.049	.051	.054	.056	.058	.061	.063	.066	.068	.071	.073
13	77	.045	.048	.050	.053	.055	.057	.060	.062	.065	.067	.069	.072
14	76	.045	.047	.049	.052	.054	.056	.059	.061	.063	.066	.068	.071
15	75	0.044	0.046	0.048	0.051	0.053	0.055	0.058	0.060	0.062	0.065	0.067	0.069
16	74	.043	.045	.047	.050	.052	.054	.056	.059	.061	.063	.065	.068
17	73	.042	.044	.046	.049	.051	.053	.055	.057	.060	.062	.064	.066
18	72	.041	.043	.045	.047	.050	.052	.054	.056	.058	.060	.062	.065
19	71	.040	.042	.044	.046	.048	.050	.052	.055	.057	.059	.061	.063
20	70	0.039	0.041	0.043	0.045	0.047	0.049	0.051	0.053	0.055	0.057	0.059	0.061
21	69	.038	.040	.042	.044	.045	.047	.049	.051	.053	.055	.057	.059
22	68	.036	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.057
23	67	.035	.037	.039	.041	.043	.044	.046	.048	.050	.052	.054	.055
24	66	.034	.036	.037	.039	.041	.043	.045	.046	.048	.050	.052	.053
25	65	0.033	0.034	0.036	0.038	0.039	0.041	0.043	0.044	0.046	0.048	0.050	0.051
26	64	.031	.033	.034	.036	.038	.039	.041	.043	.044	.046	.048	.049
27	63	.030	.031	.033	.034	.036	.038	.039	.041	.042	.044	.045	.047
28	62	.028	.030	.031	.033	.034	.036	.037	.039	.040	.042	.043	.045
29	61	.027	.028	.030	.031	.032	.034	.035	.037	.038	.039	.041	.042
30	60	0.025	0.027	0.028	0.029	0.031	0.032	0.033	0.035	0.036	0.037	0.039	0.040
31	59	.024	.025	.026	.027	.029	.030	.031	.032	.034	.035	.036	.037
32	58	.022	.023	.025	.026	.027	.028	.029	.030	.032	.033	.034	.035
33	57	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030	.031	.032
34	56	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030
35	55	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.024	0.025	0.025	0.026	0.027
36	54	.016	.016	.017	.018	.019	.020	.021	.021	.022	.023	.024	.025
37	53	.014	.015	.015	.016	.017	.018	.018	.019	.020	.021	.021	.022
38	52	.012	.013	.014	.014	.015	.015	.016	.017	.017	.018	.019	.019
39	51	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015	.016	.017
40	50	0.009	0.009	0.010	0.010	0.011	0.011	0.012	0.012	0.012	0.013	0.013	0.014
41	49	.007	.007	.008	.008	.009	.009	.009	.010	.010	.010	.011	.011
42	48	.005	.006	.006	.006	.006	.007	.007	.007	.008	.008	.008	.008
43	47	.004	.004	.004	.004	.004	.004	.005	.005	.005	.005	.005	.006
44	46	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.003	.003

* "Smithsonian Meteorological Tables," p. 58.

REDUCTION OF BAROMETER TO STANDARD GRAVITY.*

Reduction to Latitude 45°. — Metric Scale.

N. B. — From latitude 0° to 44° the correction is to be subtracted.
From latitude 90° to 46° the correction is to be added.

Latitude.		Height of the barometer in millimeters.											
		520	560	600	620	640	660	680	700	720	740	760	780
		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
0°	**90°**	1.38	1.49	1.60	1.65	1.70	1.76	1.81	1.86	1.92	1.97	2.02	2.08
5	**85**	1.36	1.47	1.57	1.63	1.68	1.73	1.78	1.84	1.89	1.94	1.99	2.04
6	84	1.35	1.46	1.56	1.61	1.67	1.72	1.77	1.82	1.87	1.93	1.98	2.03
7	83	1.34	1.45	1.55	1.60	1.65	1.70	1.76	1.81	1.86	1.91	1.96	2.01
8	82	1.33	1.43	1.54	1.59	1.64	1.69	1.74	1.79	1.84	1.89	1.94	2.00
9	81	1.32	1.42	1.52	1.57	1.62	1.67	1.72	1.77	1.82	1.87	1.92	1.97
10	**80**	1.30	1.40	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95
11	79	1.28	1.38	1.48	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.88	1.93
12	78	1.26	1.36	1.46	1.51	1.56	1.60	1.65	1.70	1.75	1.80	1.85	1.90
13	77	1.24	1.34	1.44	1.48	1.53	1.58	1.63	1.67	1.72	1.77	1.82	1.87
14	76	1.22	1.32	1.41	1.46	1.50	1.55	1.60	1.65	1.69	1.74	1.79	1.83
15	**75**	1.20	1.29	1.38	1.43	1.48	1.52	1.57	1.61	1.66	1.71	1.75	1.80
16	74	1.17	1.26	1.35	1.40	1.44	1.49	1.54	1.58	1.63	1.67	1.72	1.76
17	73	1.15	1.24	1.32	1.37	1.41	1.45	1.50	1.54	1.59	1.63	1.68	1.72
18	72	1.12	1.21	1.29	1.34	1.38	1.42	1.46	1.51	1.55	1.59	1.64	1.68
19	71	1.09	1.17	1.26	1.30	1.34	1.38	1.43	1.47	1.51	1.55	1.59	1.64
20	**70**	1.06	1.14	1.22	1.26	1.31	1.35	1.39	1.43	1.47	1.51	1.55	1.59
21	69	1.03	1.11	1.19	1.23	1.27	1.31	1.35	1.38	1.42	1.46	1.50	1.54
22	68	1.00	1.07	1.15	1.19	1.23	1.26	1.30	1.34	1.38	1.42	1.46	1.49
23	67	0.96	1.04	1.11	1.15	1.18	1.22	1.26	1.29	1.33	1.37	1.41	1.44
24	66	.93	1.00	1.07	1.10	1.14	1.18	1.21	1.25	1.28	1.32	1.35	1.39
25	**65**	0.89	0.96	1.03	1.06	1.10	1.13	1.16	1.20	1.23	1.27	1.30	1.33
26	64	.85	.92	0.98	1.02	1.05	1.08	1.11	1.15	1.18	1.21	1.25	1.28
27	63	.81	.88	.94	0.97	1.00	1.03	1.06	1.10	1.13	1.16	1.19	1.22
28	62	.77	.83	.89	.92	0.95	0.98	1.01	1.04	1.07	1.10	1.13	1.16
29	61	.73	.79	.85	.87	.90	.93	0.96	0.99	1.02	1.04	1.07	1.10
30	**60**	0.69	0.75	0.80	0.83	0.85	0.88	0.91	0.94	0.96	0.98	1.01	1.04
31	59	.65	.70	.75	.77	.80	.82	.85	.87	.90	.92	0.95	0.97
32	58	.61	.65	.70	.72	.75	.77	.79	.82	.84	.86	.89	.91
33	57	.56	.61	.65	.67	.69	.71	.74	.76	.78	.80	.82	.84
34	56	.52	.56	.60	.62	.64	.66	.68	.70	.72	.74	.76	.78
35	**55**	0.47	0.51	0.55	0.56	0.58	0.60	0.62	0.64	0.66	0.67	0.69	0.71
36	54	.43	.46	.49	.51	.53	.54	.56	.58	.59	.61	.63	.64
37	53	.38	.41	.44	.45	.47	.48	.50	.51	.53	.54	.56	.57
38	52	.33	.36	.39	.40	.41	.43	.44	.45	.46	.48	.49	.50
39	51	.29	.31	.33	.34	.35	.37	.38	.39	.40	.41	.42	.43
40	**50**	0.24	0.26	0.28	0.29	0.30	0.31	0.31	0.32	0.33	0.34	0.35	0.36
41	49	.19	.21	.22	.23	.24	.24	.25	.26	.27	.27	.28	.29
42	48	.14	.16	.17	.17	.18	.18	.19	.19	.20	.21	.21	.22
43	47	.10	.10	.11	.12	.12	.12	.13	.13	.13	.14	.14	.14
44	46	.05	.05	.06	.06	.06	.06	.06	.07	.07	.07	.07	.07

* "Smithsonian Meteorological Tables," p. 59.

TABLE 106. — Correction of the Barometer for Capillarity.*

1. METRIC MEASURE.

Diameter of tube in mm.	Height of Meniscus in Millimeters.							
	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
	Correction to be added in millimeters.							
4	0.83	1.22	1.54	1.98	2.37	–	–	–
5	.47	0.65	0.86	1.19	1.45	1.80	–	–
6	.27	.41	.56	0.78	0.98	1.21	1.43	–
7	.18	.28	.40	.53	.67	0.82	0.97	1.13
8	–	.20	.29	.38	.46	.56	.65	0.77
9	–	.15	.21	.28	.33	.40	.46	.52
10	–	–	.15	.20	.25	.29	.33	.37
11	–	–	.10	.14	.18	.21	.24	.27
12	–	–	.07	.10	.13	.15	.18	.19
13	–	–	.04	.07	.10	.12	.13	.14

2. BRITISH MEASURE.

Diameter of tube in inches.	Height of Meniscus in Inches.							
	.01	.02	.03	.04	.05	.06	.07	.08
	Correction to be added in hundredths of an inch.							
.15	2.36	4.70	6.86	9.23	11.56	–	–	–
.20	1.10	2.20	3.28	4.54	5.94	7.85	–	–
.25	0.55	1.20	1.92	2.76	3.68	4.72	5.88	
.30	.36	0.79	1.26	1.77	2.30	2.88	3.48	4.20
.35	–	.51	0.82	1.15	1.49	1.85	2.24	2.65
.40	–	.40	.61	0.81	1.02	1.22	1.42	1.62
.45	–	–	.32	.51	0.68	0.83	0.96	1.15
.50	–	–	.20	.35	.47	.56	.64	0.71
.55	–	–	.08	.20	.31	.40	.47	.52

* The first table is from Kohlrausch (Experimental Physics), and is based on the experiments of Mendelejeff and Gutkowski (Jour. de Phys. Chem. Geo. Petersburg, 1877, or Wied. Beib. 1877). The second table has been calculated from the same data by conversion into inches and graphic interpolation.

TABLE 107. — Volume of Mercury Meniscus in Cu. Mm.

Height of meniscus.	Diameter of tube in mm.										
	14	15	16	17	18	19	20	21	22	23	24
mm.											
1.6	157	185	214	245	280	318	356	398	444	492	541
1.8	181	211	244	281	320	362	407	455	507	560	616
2.0	206	240	278	319	362	409	460	513	571	631	694
2.2	233	271	313	358	406	459	515	574	637	704	776
2.4	262	303	350	400	454	511	573	639	708	781	859
2.6	291	338	388	444	503	565	633	706	782	862	948

Scheel und Heuse, Annalen der Physik, 33, p. 291, 1910.

AERODYNAMICS.

The pressure on a plane surface normal to the wind is for ordinary wind velocities expressed by

$$P = kwav^2$$

where k is a constant depending on the units employed, w the mass of unit volume of the air, a the area of the surface and v the velocity of the wind.* Engineers generally use the table of values of P given by Smeaton in 1759. This table was calculated from the formula

$$P = .00492\, v^2$$

and gives the pressure in pounds per square foot when v is expressed in miles per hour. The corresponding formula when v is expressed in feet per second is

$$P = .00228\, v^2.$$

Later determinations do not agree well together, but give on the average somewhat lower values for the coefficient. The value of w depends, of course, on the temperature and the barometric pressure. Langley's experiments give $kw = .00166$ at ordinary barometric pressure and 10° C. temperature.

For planes inclined at an angle α less than 90° to the direction of the wind the pressure may be expressed as $P_\alpha = F_\alpha P_{90}$.

Table 108, founded on the experiments of Langley, gives the value of F_α for different values of α. The word *aspect*, in the headings, is used by him to define the position of the plane relative to the direction of motion. The numerical value of the aspect is the ratio of the linear dimension transverse to the direction of motion to the linear dimension, a vertical plane through which is parallel to the direction of motion.

TABLE 108. — Values of F_α in Equation $P_\alpha = F_\alpha P_{90}$.

Plane 30 in. × 4.8 in. Aspect 6 (nearly).		Plane 12 in. × 12 in. Aspect 1.		Plane 6 in. × 24 in. Aspect ¼.	
α	F_α	α	F_α	α	F_α
0°	0.00	0°	0.00	0°	0.00
5	0.28	5	0.15	5	0.07
10	0.44	10	0.30	10	0.17
15	0.55	15	0.44	15	0.29
20	0.62	20	0.57	20	0.43
25	0.66	25	0.69	25	0.58
30	0.69	30	0.78	30	0.71
35	0.72	35	0.84	–	–
40	0.74	40	0.88	–	–
45	0.76	45	0.91	–	–
50	0.78	50	–	–	–

* The following pressures in pounds per square inch show roughly the influence of the shape and size of the resisting surface (Dines' results). The wind velocity was 20.9 miles per hour. The flat plates were ⅜ in. thick.

Square, sides 4 in.	1.51	Plate, 6 in. diam. 90° cone at back	1.49
Circle, same area	1.51	Same, cone in front	0.98
Rectangle, 16 in. by 1	1.70	" sharp 30° cone at back	1.54
Square, 12 in. sides	1.57	" cone in front	0.60
Circle, same area	1.55	5 in. Robinson cup on 8½ in. of ½ in. rod	1.68
Rectangle, 24 in. by 6	1.59	Same, with back to wind	0.73
Square, sides 16 in.	1.52	9 in. cup on 6½ in. of ⅝ in. rod	1.75
Plate, 6 in. diam. 4⅜ thick	1.45	Same, with back to wind	0.60
Ditto, curved side to wind	0.92	2½ in. cup on 9¾ in. of ¼ in. rod	2.60
Sphere, 6 in. diam.	0.67	Same, with back to wind	1.04

AERODYNAMICS.

On the basis of the results given in Table 108 Langley states the following condition for the soaring of an aeroplane 76.2 centimeters long and 12.2 centimeters broad, weighing 500 grams, — that is, a plane one square foot in area, weighing 1.1 pounds. It is supposed to soar in a horizontal direction, with aspect 6.

TABLE 109. — Data for the Soaring of Planes 76.2 × 12.2 cms. weighing 500 Grams, Aspect 6.

Inclination to the horizontal α.	Soaring speed v.		Work expended per minute (activity).		Weight of planes of like form, capable of soaring at speed v with the expenditure of one horse power.	
	Meters per sec.	Feet per sec.	Kilogram meters.	Foot pounds.	Kilograms.	Pounds.
2°	20.0	66	24	174	95.0	209
5	15.2	50	41	297	55.5	122
10	12.4	41	65	474	34.8	77
15	11.2	37	86	623	26.5	58
30	10.6	35	175	1268	13.0	29
45	11.2	37	336	2434	6.8	15

In general, if $\rho = \frac{\text{weight}}{\text{area}}$

Soaring speed $v = \sqrt{\frac{\rho}{k} \cdot \frac{1}{F_a \cos \alpha}}$

Activity per unit of weight $= v \tan \alpha$

The following data for curved surfaces are due to Wellner (Zeits. für Luftschifffahrt, x., Oct. 1893).

Let the surface be so curved that its intersection with a vertical plane parallel to the line of motion is a parabola whose height is about $\frac{1}{12}$ the subtending chord, and let the surface be bounded by an elliptic outline symmetrical with the line of motion. Also, let the angle of inclination of the chord of the surface be α, and the angle between the direction of resultant air pressure and the normal to the direction of motion be β. Then $\beta < \alpha$, and the soaring speed is

$v = \sqrt{\frac{\rho}{k} \cdot \frac{1}{F_a \cos \beta}}$, while the activity per unit of weight $= v \tan \beta$.

The following series of values were obtained from experiments on moving trains and in the wind.

Angle of inclination $\alpha =$	−3°	0°	+3°	6°	9°	12°
Inclination factor $F_a =$	0.20	0.50	0.75	0.90	1.00	1.05
$\tan \beta =$	0.01	0.02	0.03	0.04	0.10	0.17

Thus a curved surface shows finite soaring speeds when the angle of inclination α is zero or even slightly negative. Above $\alpha = 12°$ curved surfaces rapidly lose any advantage they may have for small inclinations.

TABLE 110. — Friction.

The following table of coefficients of friction f and its reciprocal $1/f$, together with the angle of friction or angle of repose ϕ, is quoted from Rankine's "Applied Mechanics." It was compiled by Rankine from the results of General Morin and other authorities, and is sufficient for all ordinary purposes.

Material.	f	$1/f$	ϕ
Wood on wood, dry	.25–.50	4.00–2.00	14.0–26.5
" " " soapy	.20	5.00	11.5
Metals on oak, dry	.50–.60	2.00–1.67	26.5–31.0
" " " wet	.24–.26	4.17–3.85	13.5–14.5
" " " soapy	.20	5.00	11.5
" " elm, dry	.20–.25	5.00–4.00	11.5–14.0
Hemp on oak, dry	.53	1.89	28.0
" " " wet	.33	3.00	18.5
Leather on oak	.27–.38	3.70–2.86	15.0–19.5
" " metals, dry	.56	1.79	29.5
" " " wet	.36	2.78	20.0
" " " greasy	.23	4.35	13.0
" " " oily	.15	6.67	8.5
Metals on metals, dry	.15–.20	6.67–5.00	8.5–11.5
" " " wet	.3	3.33	16.5
Smooth surfaces, occasionally greased	.07–.08	14.3–12.50	4.0–4.5
" " continually greased	.05	20.00	3.0
" " best results	.03–.036	33.3–27.6	1.75–2.0
Steel on agate, dry *	.20	5.00	11.5
" " " oiled *	.107	9.35	6.1
Iron on stone	.30–.70	3.33–1.43	16.7–35.0
Wood on stone	About .40	2.50	22.0
Masonry and brick work, dry	.60–.70	1.67–1.43	33.0–35.0
" " " " damp mortar	.74	1.35	36.5
" on dry clay	.51	1.96	27.0
" " moist clay	.33	3.00	18.25
Earth on earth	.25–1.00	4.00–1.00	14.0–45.0
" " " dry sand, clay, and mixed earth	.38–.75	2.63–1.33	21.0–37.0
" " " damp clay	1.00	1.00	45.0
" " " wet clay	.31	3.23	17.0
" " " shingle and gravel	.81–1.11	1.23–0.9	39.0–48.0

* Quoted from a paper by Jenkin and Ewing, "Phil. Trans. R. S." vol. 167. In this paper it is shown that in cases where "static friction" exceeds "kinetic friction" there is a gradual increase of the coefficient of friction as the speed is reduced towards zero.

TABLE 111. — Lubricants.

The best lubricants are in general the following: Low temperatures, light mineral lubricating oils. Very great pressures, slow speeds, graphite, soapstone and other solid lubricants. Heavy pressures, slow speeds, ditto and lard, tallow and other greases. Heavy pressures and high speeds, sperm oil, castor oil, heavy mineral oils. Light pressures, high speeds, sperm, refined petroleum olive, rape, cottonseed. Ordinary machinery, lard oil, tallow oil, heavy mineral oils and the heavier vegetable oils. Steam cylinders, heavy mineral oils, lard, tallow. Watches and delicate mechanisms, clarified sperm, neat's-foot, porpoise, olive and light mineral lubricating oils.

TABLE 112. — Lubricants For Cutting Tools.

Material.	Turning.	Chucking.	Drilling.	Tapping Milling.	Reaming.
Tool Steel,	dry or oil	oil or s. w.	oil	oil	lard oil
Soft Steel,	dry or soda water	soda water	oil or s. w.	oil	lard oil
Wrought iron	dry or soda water	soda water	oil or s. w.	oil	lard oil
Cast iron, brass	dry	dry	dry	dry	dry
Copper	dry	dry	dry	dry	mixture
Glass	turpentine or kerosene				

Mixture = ⅓ crude petroleum, ⅔ lard oil. Oil = sperm or lard.

Tables 111 and 112 quoted from "Friction and Lost Work in Machinery and Mill Work," Thurston, Wiley and Sons.

VISCOSITY.

The coefficient of viscosity is the tangential force per unit area of one face of a plate of the fluid which is required to keep up unit distortion between the faces. Viscosity is thus measured in terms of the temporary rigidity which it gives to the fluid. Solids may be included in this definition when only that part of the rigidity which is due to varying distortion is considered. One of the most satisfactory methods of measuring the viscosity of fluids is by the observation of the rate of flow of the fluid through a capillary tube, the length of which is great in comparison with its diameter. Poiseuille * gave the following formula for calculating the viscosity coefficient in this case: $\mu = \frac{\pi h r^4 s}{8vl}$, where h is the pressure height, r the radius of the tube, s the density of the fluid, v the quantity flowing per unit time, and l the length of the capillary part of the tube. The liquid is supposed to flow from an upper to a lower reservoir joined by the tube, hence h and l are different. The product hs is the pressure under which the flow takes place. Hagenbach † pointed out that this formula is in error if the velocity of flow is sensible, and suggested a correction which was used in the calculation of his results. The amount to be subtracted from h, according to Hagenbach, is $\frac{v^2}{\sqrt{2}\cdot g}$, where g is the acceleration due to gravity. Gartenmeister ‡ points out an error in this to which his attention had been called by Finkener, and states that the quantity to be subtracted from h should be simply $\frac{v^2}{g}$; and this formula is used in the reduction of his observations. Gartenmeister's formula is the most accurate, but all of them nearly agree if the tube be long enough to make the rate of flow very small. None of the formulæ take into account irregularities in the distortion of the fluid near the ends of the tube, but this is probably negligible in all cases here quoted from, although it probably renders the results obtained by the "viscosimeter" commonly used for testing oils useless for our purpose.

The term "specific viscosity" is sometimes used in the headings of the tables; it means the ratio of the viscosity of the fluid under consideration to the viscosity of water at a specified temperature.

The friction of a fluid is proportional to the size of the rubbing surface, to $\frac{dv}{dx}$, where v is the velocity of motion in a direction perpendicular to the rubbing surface, and to a constant known as the viscosity.

(a) Variation of Viscosity of Water, with Temperature. Dynes per sq. cm.

Temp. C.	Poiseville. 1846.	Sprung. 1876.	Slotte. 1883.	Thorpe-Rogers. 1894.§	Hosking. 1909.‖	Temp. C.	Slotte. 1883.	Thorpe-Rogers 1894.	Hosking. 1909.‖
0°	0.01716	0.01778	0.01808	0.01778	0.01793	55°	0.00510	0.00506	.00508
5	.01515	.01510	.01524	.01510	.01522	60	.00472	.00468	.00469
10	.01309	.01301	.01314	.01303	.01310	65	.00438	.00436	.00436
15	.01146	.01135	.01144	.01134	.01142	70	.00408	.00406	.00406
20	.01008	.01003	.01008	.01002	.01006	75	.00382	.00380	.00380
25	.00897	.00896	.00896	.00891	.00893	80	.00358	.00356	.00356
30	.00803	.00802	.00803	.00798	.00800	85	.00337	.00335	.00335
35	.00721	.00723	.00724	.00720	.00724	90	.00318	.00316	.00316
40	.00653	.00657	.00657	.00654	.00657	95	.00301	.00299	.00300
45	.00595	.00602	.00602	.00597	.00600	100	.00285	.00283	.00284¶
50	–	.00553	.00553	.00548	.00550	153		–	.00181¶

(b) Variation of Specific Viscosity of Water with Temperature. ‖

0°	1.000	25°	0.498	50°	0.307	75°	0.212	100°	0.158
5°	.849	30	.446	55	.283	80	.199	124°	.124¶
10°	.730	35	.404	60	.262	85	.187	153°	.101¶
15°	.637	40	.367	65	.243	90	.176	–	–
20°	.561	45	.335	70	.226	95	.167	–	–

* "Comptes rendus," vol. 15, 1842; "Mém. Serv. Étr." 1846.
† "Pogg. Ann." vol. 109, 1860.
‡ "Zeitschr. Phys. Chem." vol. 6, 1890.
§ Thorpe and Rogers, "Philos. Trans." 185A, p. 397, 1894; "Proc. Roy. Soc." 55, p. 148, 1894.
‖ Hosking, Phil. Mag. 17, p. 502, 1909; 18, p. 260, 1909.
¶ de Haas, Diss. Leiden, 1894.

VISCOSITY.

TABLE 114. — Solution of Alcohol in Water.*

Coefficients of viscosity, in C. G. S. units, for solution of alcohol in water.

Temp. C.	Percentage by weight of alcohol in the mixture.								
	0	8.21	16.60	34.58	43.99	53.36	75.75	87.45	99.72
0°	0.0181	0.0287	0.0453	0.0732	0.0707	0.0632	0.0407	0.0294	0.0180
5	.0152	.0234	.0351	.0558	.0552	.0502	.0344	.0256	.0163
10	.0131	.0195	.0281	.0435	.0438	.0405	.0292	.0223	.0148
15	.0114	.0165	.0230	.0347	.0353	.0332	.0250	.0195	.0134
20	.0101	.0142	.0193	.0283	.0286	.0276	.0215	.0172	.0122
25	0.0090	0.0123	0.0163	0.0234	0.0241	0.0232	0.0187	0.0152	0.0110
30	.0081	.0108	.0141	.0196	.0204	.0198	.0163	.0135	.0100
35	.0073	.0096	.0122	.0167	.0174	.0171	.0144	.0120	.0092
40	.0067	.0086	.0108	.0143	.0150	.0149	.0127	.0107	.0084
45	.0061	.0077	.0095	.0125	.0131	.0130	.0113	.0097	.0077
50	0.0056	0.0070	0.0085	0.0109	0.0115	0.0115	0.0102	0.0088	0.0070
55	.0052	.0063	.0076	.0096	.0102	.0102	.0091	.0086	.0065
60	.0048	.0058	.0069	.0086	.0091	.0092	.0083	.0073	.0060

The following tables (115–116) contain the results of a number of experiments in the viscosity of mineral oils derived from petroleum residues and used for lubricating purposes.†

TABLE 115. — Mineral Oils.‡

Density.	Flashing point. ° C.	Burning point. ° C.	Sp. viscosity. Water at 20° C. = 1. 20° C.	50° C.	100° C.
.931	243	274	–	11.30	2.9
.921	216	246	–	7.31	2.5
.906	189	208	–	3.45	1.5
.921	163	190	–	27.80	2.8
.917	132	168	–	–	2.6
.904	170	207	8.65	2.65	1.7
.891	151	182	4.77	1.86	1.3
.878	108	148	2.94	1.48	–
.855	42	45	1.65	–	–
.905	165	202	–	3.10	1.5
.894	139	270	7.60	3.60	1.3
.866	90	224	2.50	1.50	–

TABLE 116. — Oils.

Oil.	Density.	Flashing point. ° C.	Burning point. ° C.	Viscosity at 19° C., water at 19° C. = 1.
Cylinder oil . .	.917	227	274	191
Machine oil . .	.914	213	260	102
Wagon oil . .	.914	148	182	80
" " . .	.911	157	187	70
Naphtha residue	.910	134	162	55
Oleo-naphtha .	.910	219	257	121
" " .	.904	201	242	66
" " .	.894	184	222	26
Oleonid . . .	.884	185	217	28
" best quality	.881	188	224	20
Olive oil . . .	.916	–	–	22
Whale oil . .	.879		–	9
" " . .	.875	–	–	8

* This table was calculated from the table of fluidities given by Noack (Wied. Ann. vol. 27, p. 217), and shows a maximum for a solution containing about 40 per cent of alcohol. A similar result was obtained for solutions of acetic acid.

† Table 115 is from a paper by Engler in Dingler's "Poly. Jour." vol. 268, p. 76, and Table 116 is from a paper by Lamansky in the same journal, vol. 248, p. 29. The very mixed composition of these oils renders the viscosity a very uncertain quantity, neither the density nor the flashing point being a good guide to viscosity.

‡ The different groups in this table are from different residues.

Table 117.

VISCOSITY.

This table gives some miscellaneous data as to the viscosity of liquids, mostly referring to oils and paraffins. The viscosities are in C. G. S. units.

Liquid.	G. %	Coefficient of viscosity.	Temp. Cent.°	Authority.
Ammonia		0.0160	11.9	Poiseuille.
"		0.0149	14.5	"
Anisol		0.0111	20.0	Gartenmeister.
Colophonium		3×10^{16}	15.	Reiger.
Di-ethyl ether		0.00276	6.7°	Thorpe, Roger.
Glycerine		42.20	2.8	Schottner.
"		25.18	8.1	"
"		13.87	14.3	"
"		8.30	20.3	"
"		4.94	26.5	"
Glycerine and water	94.46	7.437	8.5	"
" "	80.31	1.021	8.5	"
" "	64.05	0.222	8.5	"
" "	49.79	0.092	8.5	"
Glycol		0.0219	0.0	Arrhenius.
Menthol, solid		209×10^{10}	14.9	Heydweiller.
" liquid		0.069	34.9	"
Mercury*		0.0184	—20	Koch.
"		0.0170	0.0	"
"		0.0157	20.0	"
"		0.0122	100.0	"
"		0.0102	200.0	"
"		0.0093	300.0	"
Meta-cresol		0.1878	20.0	Gartenmeister.
Olive oil		0.9890	15.0	Brodmann.
Paraffins: Decane		0.0077	22.3	Bartolli & Stracciati.
Dodecane		0.0126	23.3	" "
Heptane		0.0045	24.0	" "
Hexadecane		0.0359	22.2	" "
Hexane		0.0033	23.7	" "
Nonane		0.0062	22.3	" "
Octane		0.0053	22.2	" "
Pentane		0.0026	21.0	" "
Pentadecane		0.0281	22.0	" "
Tetradecane		0.0213	21.9	" "
Tridecane		0.0155	23.3	" "
Undecane		0.0095	22.7	" "
Petroleum (Caucasian)		0.0190	17.5	Petroff.
Phenol		0.127	18.3	Scarpa.
Rape oil		25.3	0.0	O. E. Meyer.
" "		3.85	10.0	"
" "		1.63	20.0	"
" "		0.96	30.0	"

* Calculated from the formula $\mu = .017 - .000066t + .0000021t^2 - .0000000025t^3$ (vide Koch, Wied. Ann. vol. 14, p. 1881).

Table 118.

VISCOSITY.

This table gives the viscosity of a number of liquids together with their temperature variation. The headings are temperatures in Centigrade degrees, and the numbers under them the coefficients of viscosity in C. G. S. units.*

Liquid.	Temperature Centigrade.								Reference.
	0°	10°	20°	30°	40°	50°	70°	90°	
Acetates: Methyl	–	.0046	.0041	.0036	.0032	.0030	–	–	1
Ethyl	–	.0051	.0044	.0040	.0035	.0032	–	–	1
Propyl	–	.0066	.0059	.0052	.0044	.0039	–	–	1
Allyl	–	.0068	.0061	.0054	.0049	.0044	–	–	1
Amyl	–	.0106	.0089	.0077	.0065	.0058	–	–	1
Acids: Formic	–	.02262	.01804	.01465	.01224	.01025	–	–	2
Acetic	–	.0150	.0126	.0109	.0094	.0082	–	–	1
Propionic	–	.0125	.0107	.0092	.0081	.0073	–	–	3
"	–	.0139	.0118	.0101	.0091	.0080	–	–	1
Butyric	–	.0196	.0163	.0136	.0118	.0102	–	–	2
Valeric	–	.0271	.0220	.0183	.0155	.0127	–	–	3
Salicylic	–	.0320	.0271	.0222	.0181	.0150	–	–	3
Alcohol: Methyl	.00813	.00686	.00591	.00515	.00450	.00396	–	–	4
Ethyl	.01770	.01449	.01192	.00990	.00828	.00698	.00504	–	4
Propyl	.03882	.02917	.02255	.01778	.01403	.01128	.00757	.00526	4
Butyric	.05185	.03872	.02947	.02266	.01780	.01409	.00926	.00633	4
Allyl	.02144	.01703	.01361	.01165	.00911	.00760	.00548	.00407	4
Isopropyl	.04564	.03245	.02369	.01755	.01329	.01026	.00642	–	4
Isobutyl	.08038	.05547	.03906	.02863	.02121	.01609	.00973	.00633	4
Amyl (op.-inac.)	.08532	.06000	.04341	.03206	.02414	.01849	.01147	.00758	4
Aldehyde	.00267	.00244	.00222	–	–	–	–	–	3
Aniline	–	–	.0440	.0319	.0241	.0189	–	–	5
Benzole	.00902	.00759	.00649	.00562	.00492	.00437	.00351	–	4
Bromides: Ethyl	.00478	.00432	.00392	.00357	–	–	–	–	4
Propyl	.00645	.00575	.00517	.00467	.00425	.00388	.00328	–	4
Allyl	.00619	.00552	.00496	.00449	.00410	.00374	.00316	–	4
Ethylene	.02435	.02035	.01716	.01470	.01280	.01124	.00895	.00733	4
Carbon bisulphide	.00429	.00396	.00367	.00342	.00319	–	–	–	4
Carbon dioxide (liq.)	.00099	.00085	.00071	–	–	–	–	–	6
Chlorides: Propyl	.00436	.00390	.00352	.00319	.00291	–	–	–	4
Allyl	.00402	.00358	.00322	.00292	–	–	–	–	4
Ethylene	.01128	.00961	.00833	.00730	.00646	.00576	.00470	–	4
Chloroform	.00700	.00626	.00564	.00511	.00466	.00390	–	–	4
Ether	–	.0026	.0023	.0021	–	–	–	–	1
Ethylbenzole	.00874	.00758	.00666	.00592	.00529	.00477	.00394	.00330	4
Ethylsulphide	.00559	.00496	.00444	.00401	.00363	.00331	.00279	.00237	4
Iodides: Methyl	.00594	.00536	.00487	.00446	.00409	–	–	–	
Ethyl	.00719	.00645	.00583	.00530	.00484	.00444	.00378	–	
Propyl	.00938	.00827	.00737	.00662	.00598	.00544	.00456	.00387	4
Allyl	.00930	.00819	.00726	.00652	.00588	.00534	.00448	.00381	4
Metaxylol	.00802	.00698	.00615	.00547	.00491	.00444	.00369	.00313	4
Nitrobenzene	–	–	.0203	.0170	.0144	.0124	–	–	1
Paraffines: Pentane	.00283	.00256	.00232	.00212	–	–	–	–	4
Hexane	.00396	.00355	.00320	.00290	.00264	.00241	.00221	–	4
Heptane	.00519	.00460	.00410	.00369	.00334	.00303	.00253	.00214	4
Octane	.00703	.00612	.00538	.00478	.00428	.00386	.00318	.00266	4
Isopentane	.00273	.00246	.00223	.00204	–	–	–	–	4
Isohexane	.00371	.00332	.00300	.00272	.00247	.00226	–	–	4
Isoheptane	.00477	.00423	.00379	.00342	.00309	.00282	.00235	.00200	4
Propyl aldehyde	–	.0047	.0041	.0036	.0033	–	–	–	1
Toluene	.00768	.00668	.00586	.00520	.00466	.00420	.00348	.00292	4

1 Pribram-Handl, Wien. Ber. 78, 1878, 80, 1879, 84, 1881.
2 Gartenmeister, Zeitschr. Phys. Chem. 6, 1890.
3 Rellstab, Diss. Bonn, 1868.
4 Thorpe-Roger, Philos. Trans. 185 A, 1894, 189 A, 1897; Proc. Roy. Soc. 55, 1894, 60, 1896; Jour. Chem. Soc. 71, 1897; Chem. News, 75, 1897.
5 Wijkander, Wied. Beibl. 3, 1879.
6 Warburg-Babo, Wied. Ann. 17, 1882.

* Calculated from the specific viscosities given in Landolt & Börnstein's Phys. Chem. Tab.

For inorganic acids, see Solutions.

VISCOSITY OF SOLUTIONS.

This table is intended to show the effect of change of concentration and change of temperature on the viscosity of solutions of salts in water. The specific viscosity × 100 is given for two or more densities and for several temperatures in the case of each solution. μ stands for specific viscosity, and *t* for temperature Centigrade.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$BaCl_2$	7.60	–	77.9	10	44.0	30	35.2	50		–	Sprung.
"	15.40	–	86.4	"	56.0	"	39.6	"	–	–	"
"	24.34	–	100.7	"	66.2	"	47.7	"	–	–	"
$Ba(NO_3)_2$	2.98	1.027	62.0	15	51.1	25	42.4	35	34.8	45	Wagner.
"	5.24	1.051	68.1	"	54.2	"	44.1	"	36.9	"	"
$CaCl_2$	15.17	–	110.9	10	71.3	30	50.3	50	–		Sprung.
"	31.60	–	272.5	"	177.0	"	124.0	"	–	–	"
"	39.75	–	670.0	"	379.0	"	245.5	"	–	–	"
"	44.09	–	–	–	593.1	"	363.2	"	–	–	"
$Ca(NO_3)_2$	17.55	1.171	93.8	15	74.6	25	60.0	35	49.9	45	Wagner.
"	30.10	1.274	144.1	"	112.7	"	90.7	"	75.1	"	"
"	40.13	1.386	242.6	"	217.1	"	156.5	"	128.1	"	"
$CdCl_2$	11.09	1.109	77.5	15	60.5	25	49.1	35	40.7	45	"
"	16.30	1.181	88.9	"	70.5	"	57.5	"	47.2	"	"
"	24.79	1.320	104.0	"	80.4	"	64.6	"	53.6	"	"
$Cd(NO_3)_2$	7.81	1.074	61.9	15	50.1	25	41.1	35	34.0	45	"
"	15.71	1.159	71.8	"	58.7	"	48.8	"	41.3	"	"
"	22.36	1.241	85.1	"	69.0	"	57.3	"	47.5	"	"
$CdSO_4$	7.14	1.068	78.9	15	61.8	25	49.9	35	41.3	45	"
"	14.66	1.159	96.2	"	72.4	"	58.1	"	48.8	"	"
"	22.01	1.268	120.8	"	91.8	"	73.5	"	60.1	"	"
$CoCl_2$	7.97	1.081	83.0	15	65.1	25	53.6	35	44.9	45	"
"	14.86	1.161	111.6	"	85.1	"	73.7	"	58.8	"	"
"	22.27	1.264	161.6	"	126.6	"	101.6	"	85.6	"	"
$Co(NO_3)_2$	8.28	1.073	74.7	15	57.9	25	48.7	35	39.8	45	"
"	15.96	1.144	87.0	"	69.2	"	55.4	"	44.9	"	"
"	24.53	1.229	110.4	"	88.0	"	71.5	"	59.1	"	"
$CoSO_4$	7.24	1.086	86.7	15	68.7	25	55.0	35	45.1	45	"
"	14.16	1.159	117.8	"	95.5	"	76.0	"	61.7	"	"
"	21.17	1.240	193.6	"	146.2	"	113.0	"	89.9	"	"
$CuCl_2$	12.01	1.104	87.2	15	67.8	25	55.1	35	45.6	45	"
"	21.35	1.215	121.5	"	95.8	"	77.0	"	63.2	"	"
"	33.03	1.331	178.4	"	137.2	"	107.6	"	87.1	"	"
$Cu(NO_3)_2$	18.99	1.177	97.3	15	76.0	25	61.5	35	51.3	45	"
"	26.68	1.264	126.2	"	98.8	"	80.9	"	68.6	"	"
"	46.71	1.536	382.9	"	283.8	"	215.3	"	172.2	"	"
$CuSO_4$	6.79	1.055	79.6	15	61.8	25	49.8	35	41.4	45	"
"	12.57	1.115	98.2	"	74.0	"	59.7	"	52.0	"	"
"	17.49	1.163	124.5	"	96.8	"	75.9	"	61.8	"	"
HCl	8.14	1.037	71.0	15	57.9	25	48.3	35	40.1	45	"
"	16.12	1.084	80.0	"	66.5	"	56.4	"	48.1	"	"
"	23.04	1.114	91.8	"	79.9	"	65.9	"	56.4	"	"
$HgCl_2$	0.23	1.002	–	–	58.5	20	46.8	30	38.3	40	"
"	3.55	1.033	76.75	10	59.2	"	46.6	"	38.3	"	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
HNO_3	8.37	1.067	66.4	15	54.8	25	45.4	35	37.6	45	Wagner.
"	12.20	1.116	69.5	"	57.3	"	47.9	"	40.7	"	"
"	28.31	1.178	80.3	"	65.5	"	54.9	"	46.2	"	"
H_2SO_4	7.87	1.065	77.8	15	61.0	25	50.0	35	41.7	45	"
"	15.50	1.130	95.1	"	75.0	"	60.5	"	49.8	"	"
"	23.43	1.200	122.7	"	95.5	"	77.5	"	64.3	"	"
KCl	10.23		70.0	10	46.1	30	33.1	50	–	–	Sprung.
"	22.21	-	70.0	"	48.6	"	36.4	"	–	–	"
KBr	14.02		67.6	10	44.8	30	32.1	50	–	–	"
"	23.16	–	66.2	"	44.7	"	33.2	"	–	–	"
"	34.64	–	66.6	"	47.0	"	35.7	"	–	–	"
KI	8.42	–	69.5	10	44.0	30	31.3	50	–	–	"
"	17.01	–	65.3	"	42.9	"	31.4	"	–	–	"
"	33.03		61.8	"	42.9	"	32.4	"	–	–	"
"	45.98	–	63.0	"	45.2	"	35.3	"	–	–	"
"	54.00	–	68.8	"	48.5	"	37.6	"	–	–	"
$KClO_3$	3.51	–	71.7	10	44.7	30	31.5	50	–	–	"
"	5.69	–	–	"	45.0	"	31.4	"	–	–	"
KNO_3	6.32	–	70.8	10	44.6	30	31.8	50	–	–	"
"	12.19		68.7	"	44.8	"	32.3	"	–	–	"
"	17.60	–	68.8	"	46.0	"	33.4	"	–	–	"
K_2SO_4	5.17	–	77.4	10	48.6	30	34.3	50	–	–	"
"	9.77	–	81.0	"	52.0	"	36.9	"	–	–	"
K_2CrO_4	11.93	–	75.8	10	62.5	30	41.0	40	–	–	"
"	19.61	–	85.3	"	68.7	"	47.9	"	–	–	"
"	24.26	1.233	97.8	"	74.5	"	54.5	"	–	–	Slotte.
"	32.78	–	109.5	"	88.9	"	62.6	"	–	–	Sprung.
$K_2Cr_2O_7$	4.71	1.032	72.6	10	55.9	20	45.3	30	37.5	40	Slotte.
"	6.97	1.049	73.1	"	56.4	"	45.5	"	37.7	"	"
LiCl	7.76	–	96.1	10	59.7	30	41.2	50	–	–	Sprung.
"	13.91	–	121.3	"	75.9	"	52.6	"	–	–	"
"	26.93	–	229.4	"	142.1	"	98.0	"	–	–	"
$Mg(NO_3)_2$	18.62	1.102	99.8	15	81.3	25	66.5	35	56.2	45	Wagner.
"	34.19	1.200	213.3	"	164.4	"	132.4	"	109.9	"	"
"	39.77	1.430	317.0	"	250.0	"	191.4	"	158.1	"	"
$MgSO_4$	4.98	–	96.2	10	59.0	30	40.9	50	–	–	Sprung.
"	9.50	–	130.9	"	77.7	"	53.0	"	–	–	"
"	19.32	–	302.2	"	166.4	"	106.0	"	–	–	"
$MgCrO_4$	12.31	1.089	111.3	10	84.8	20	67.4	30	55.0	40	Slotte.
"	21.86	1.164	167.1	"	125.3	"	99.0	"	79.4	"	"
"	27.71	1.217	232.2	"	172.6	"	133.9	"	106.6	"	"
$MnCl_2$	8.01	1.096	92.8	15	71.1	25	57.5	35	48.1	45	Wagner.
"	15.65	1.196	130.9	"	104.2	"	84.0	"	68.7	"	"
"	30.33	1.337	256.3	"	193.2	"	155.0	"	123.7	"	"
"	40.13	1.453	537.3	"	393.4	"	300.4	"	246.5	"	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$Mn(NO_3)_2$	18.31	1.148	96.0	15	76.4	25	64.5	35	55.6	45	Wagner.
"	29.60	1.323	167.5	"	126.0	"	104.6	"	88.6	"	"
"	49.31	1.506	396.8	"	301.1	"	221.0	"	188.8	"	"
$MnSO_4$	11.45	1.147	129.4	15	98.6	25	78.3	35	63.4	45	"
"	18.80	1.251	228.6	"	172.2	"	137.1	"	107.4	"	"
"	22.08	1.306	661.8	"	474.3	"	347.9	"	266.8	"	"
$NaCl$	7.95	–	82.4	10	52.0	30	31.8	50	–		Sprung.
"	14.31	–	94.8	"	60.1	"	36.9	"			"
"	23.22	–	128.3	"	79.4	"	47.4	"	–	–	"
$NaBr$	9.77	–	75.6	10	48.7	30	34.4	50	–	–	"
"	18.58	–	82.6	"	53.5	"	38.2	"	–	–	"
"	27.27	–	95.9	"	61.7	"	43.8	"	–	–	"
NaI	8.83	–	73.1	10	46.0	30	32.4	50	–	–	"
"	17.15	–	73.8	"	47.4	"	33.7	"	–	–	"
"	35.69	–	86.0	"	55.7	"	40.6	"	–	–	"
"	55.47	–	157.2	"	96.4	"	66.9	"		–	"
$NaClO_3$	11.50	–	78.7	10	50.0	30	35.3	50	–	–	"
"	20.59	–	88.9	"	56.8	"	40.4	"	–	–	"
"	33.54	–	121.0	"	75.7	"	53.0	"	–	–	"
$NaNO_3$	7.25	–	75.6	10	47.9	30	33.8	50	–	–	"
"	12.35	–	81.2	"	51.0	"	36.1	"	–	–	"
"	18.20	–	87.0	"	55.9	"	39.3	"	–	–	"
"	31.55	–	121.2	"	76.2	"	53.4	"	–	–	"
Na_2SO_4	4.98	–	96.2	10	59.0	30	40.9	50	–	–	"
"	9.50	–	130.9	"	77.7	"	53.0	"	–	–	"
"	14.03	–	187.9	"	107.4	"	71.1	"	–	–	"
"	19.32	–	302.2	"	166.4	"	106.0	"	–	–	"
Na_2CrO_4	5.76	1.058	85.8	10	66.6	20	53.4	30	43.8	40	Slotte.
"	10.62	1.112	103.3	"	79.3	"	63.5	"	52.3	"	"
"	14.81	1.164	127.5	"	97.1	"	77.3	"	63.0	"	"
NH_4Cl	3.67	–	71.5	10	45.0	30	31.9	50	–	–	Sprung.
"	8.67	–	69.1	"	45.3	"	32.6	"	–		"
"	15.68	–	67.3	"	46.2	"	34.0	"	–	–	"
"	23.37	–	67.4	"	47.7	"	36.1	"		–	"
NH_4Br	15.97	–	65.2	10	43.2	30	31.5	50	–	–	"
"	25.33	–	62.6	"	43.3	"	32.2	"	–	–	"
"	36.88	–	62.4	"	44.6	"	34.3	"	–	–	"
NH_4NO_3	5.97	–	69.6	10	44.3	30	31.6	50	–	–	"
"	12.19	–	66.8	"	44.3	"	31.9	"	–	–	"
"	27.08	–	67.0	"	47.7	"	34.9	"	–	–	"
"	37.22	–	71.7	"	51.2	"	38.8	"	–	–	"
"	49.83	–	81.1	"	63.3	"	48.9	"	–	–	"
$(NH_4)_2SO_4$	8.10	–	107.9	10	52.3	30	37.0	50	–		"
"	15.94	–	120.2	"	60.4	"	43.2	"		–	"
"	25.51	–	148.4	"	74.8	"	54.1	"	–	–	"

VISCOSITY OF SOLUTIONS.

Salt.	Percentage by weight of salt in solution.	Density.	μ	t	μ	t	μ	t	μ	t	Authority.
$(NH_4)_2CrO_4$	10.52	1.063	79.3	10	62.4	20	–	–	42.4	40	Slotte.
"	19.75	1.120	88.2	"	70.0	"	57.8	30	48.4	–	"
"	28.04	1.173	101.1	"	80.7	"	60.8	"	56.4	–	"
$(NH_4)_2Cr_2O_7$	6.85	1.039	72.5	10	56.3	20	45.8	30	38.0	40	"
"	13.00	1.078	72.6	"	57.2	"	46.8	"	39.1	"	"
"	19.93	1.126	77.6	"	58.8	"	48.7	"	40.9	"	"
$NiCl_2$	11.45	1.109	90.4	15	70.0	25	57.5	35	48.2	45	Wagner.
"	22.69	1.226	140.2	"	109.7	"	87.8	"	72.7	"	"
"	30.40	1.337	229.5	"	171.8	"	139.2	"	111.9	"	"
$Ni(NO_3)_2$	16.49	1.136	90.7	15	70.1	25	57.4	35	48.9	45	"
"	30.01	1.278	135.6	"	105.9	"	85.5	"	70.7	"	"
"	40.95	1.388	222.6	"	169.7	"	128.2	"	152.4	"	"
$NiSO_4$	10.62	1.092	94.6	15	73.5	25	60.1	35	49.8	45	"
"	18.19	1.198	154.9	"	119.9	"	99.5	"	75.7	"	"
"	25.35	1.314	298.5	"	224.9	"	173.0	"	152.4	"	"
$Pb(NO_3)_2$	17.93	1.179	74.0	15	59.1	25	48.5	35	40.3	45	"
"	32.22	1.362	91.8	"	72.5	"	59.6	"	50.6	"	"
$Sr(NO_3)_2$	10.29	1.088	69.3	15	56.0	25	45.9	35	39.1	45	"
"	21.19	1.124	87.3	"	69.2	"	57.8	"	48.1	"	"
"	32.61	1.307	116.9	"	93.3	"	76.7	"	62.3	"	"
$ZnCl_2$	15.33	1.146	93.6	15	72.7	25	57.8	35	48.2	45	"
"	23.49	1.229	111.5	"	86.6	"	69.8	"	57.5	"	"
"	33.78	1.343	151.7	"	117.9	"	90.0	"	72.6	"	"
$Zn(NO_3)_2$	15.95	1.115	80.7	15	64.3	25	52.6	35	43.8	45	"
"	30.23	1.229	104.7	"	85.7	"	69.5	"	57.7	"	"
"	44.50	1.437	167.9	"	130.6	"	105.4	"	87.9	"	"
$ZnSO_4$	7.12	1.106	97.1	15	79.3	25	62.7	35	51.5	45	"
"	16.64	1.195	156.0	"	118.6	"	94.2	"	73.5	"	"
"	23.09	1.281	232.8	"	177.4	"	135.2	"	108.1	"	"

TABLE 120.

SPECIFIC VISCOSITY.*

Dissolved salt.	Normal solution.		½ normal.		¼ normal.		⅛ normal.		Authority.
	Density.	Specific viscosity.	Density.	Specific viscosity.	Density.	Specific viscosity.	Density.	Specific viscosity.	
Acids : Cl_2O_3 . .	1.0562	1.012	1.0283	1.003	1.0143	1.000	1.0074	0.999	Reyher.
HCl . . .	1.0177	1.067	1.0092	1.034	1.0045	1.017	1.0025	1.009	"
$HClO_3$ . .	1.0485	1.052	1.0244	1.025	1.0126	1.014	1.0064	1.006	"
HNO_3 . .	1.0332	1.027	1.0168	1.011	1.0086	1.005	1.0044	1.003	"
H_2SO_4 . .	1.0303	1.090	1.0154	1.043	1.0074	1.022	1.0035	1.008	Wagner.
Aluminium sulphate	1.0550	1.406	1.0278	1.178	1.0138	1.082	1.0068	1.038	"
Barium chloride . .	1.0884	1.123	1.0441	1.057	1.0226	1.026	1.0114	1.013	"
" nitrate . .	–	–	1.0518	1.044	1.0259	1.021	1.0130	1.008	"
Calcium chloride .	1.0446	1.156	1.0218	1.076	1.0105	1.036	1.0050	1.017	"
" nitrate . .	1.0596	1.117	1.0300	1.053	1.0151	1.022	1.0076	1.008	"
Cadmium chloride .	1.0779	1.134	1.0394	1.063	1.0197	1.031	1.0098	1.020	"
" nitrate .	1.0954	1.165	1.0479	1.074	1.0249	1.038	1.0119	1.018	"
" sulphate .	1.0973	1.348	1.0487	1.157	1.0244	1.078	1.0120	1.033	"
Cobalt chloride . .	1.0571	1.204	1.0286	1.097	1.0144	1.048	1.0058	1.023	"
" nitrate . .	1.0728	1.166	1.0369	1.075	1.0184	1.032	1.0094	1.018	"
" sulphate . .	1.0750	1.354	1.0383	1.160	1.0193	1.077	1.0110	1.040	"
Copper chloride . .	1.0624	1.205	1.0313	1.098	1.0158	1.047	1.0077	1.027	"
" nitrate . .	1.0755	1.179	1.0372	1.080	1.0185	1.040	1.0092	1.018	"
" sulphate .	1.0790	1.358	1.0402	1.160	1.0205	1.080	1.0103	1.038	"
Lead nitrate . . .	1.1380	1.101	0.0699	1.042	1.0351	1.017	1.0175	1.007	"
Lithium chloride .	1.0243	1.142	1.0129	1.066	1.0062	1.031	1.0030	1.012	"
" sulphate .	1.0453	1.290	1.0234	1.137	1.0115	1.065	1.0057	1.032	"
Magnesium chloride	1.1375	1.201	1.0188	1.094	1.0091	1.044	1.0043	1.021	"
" nitrate .	1.0512	1.171	1.0259	1.082	1.0130	1.040	1.0066	1.020	"
" sulphate	1.0584	1.367	1.0297	1.164	1.0152	1.078	1.0076	1.032	"
Manganese chloride	1.0513	1.209	1.0259	1.098	1.0125	1.048	1.0063	1.023	"
" nitrate .	1.0690	1.183	1.0349	1.087	1.0174	1.043	1.0093	1.023	"
" sulphate	1.0728	1.364	1.0365	1.169	1.0179	1.076	1.0087	1.037	"
Nickel chloride . .	1.0591	1.205	1.0308	1.097	1.0144	1.044	1.0067	1.021	"
" nitrate . . .	1.0755	1.180	1.0381	1.084	1.0192	1.042	1.0096	1.019	"
" sulphate . .	1.0773	1.361	1.0391	1.161	1.0198	1.075	1.0017	1.032	"
Potassium chloride .	1.0466	0.987	1.0235	0.987	1.0117	0.990	1.0059	0.993	"
" chromate	1.0935	1.113	1.0475	1.053	1.0241	1.022	1.0121	1.012	"
" nitrate .	1.0605	0.975	1.0305	0.982	1.0161	0.987	1.0075	0.992	"
" sulphate	1.0664	1.105	1.0338	1.049	1.0170	1.021	1.0084	1.008	"
Sodium chloride . .	1.0401	1.097	1.0208	1.047	1.0107	1.024	1.0056	1.013	Reyher.
" bromide . .	1.0786	1.064	1.0396	1.030	1.0190	1.015	1.0100	1.008	"
" chlorate .	1.0710	1.090	1.0359	1.042	1.0180	1.022	1.0092	1.012	"
" nitrate . .	1.0554	1.065	1.0281	1.026	1.0141	1.012	1.0071	1.007	"
Silver nitrate . . .	1.1386	1.058	1.0692	1.020	1.0348	1.006	1.0173	1.000	Wagner.
Strontium chloride .	1.0676	1.141	1.0336	1.067	1.0171	1.034	1.0084	1.014	"
" nitrate .	1.0822	1.115	1.0419	1.049	1.0208	1.024	1.0104	1.011	"
Zinc chloride . . .	1.0590	1.189	1.0302	1.096	1.0152	1.053	1.0077	1.024	"
" nitrate . . .	1.0758	1.164	1.0404	1.086	1.0191	1.039	1.0096	1.019	"
" sulphate . . .	1.0792	1.367	1.0402	1.173	1.0198	1.082	1.0094	1.036	"

* In the case of solutions of salts it has been found (*vide* Arrhennius, Zeits. für Phys. Chem. vol. 1, p. 285) that the specific viscosity can, in many cases, be nearly expressed by the equation $\mu = \mu_1^n$, where μ_1 is the specific viscosity for a normal solution referred to the solvent at the same temperature, and n the number of gramme molecules in the solution under consideration. The same rule may of course be applied to solutions stated in percentages instead of gramme molecules. The table here given has been compiled from the results of Reyher (Zeits. für Phys. Chem. vol. 2, p. 749) and of Wagner (Zeits. für Phys. Chem. vol. 5, p. 31) and illustrates this rule. The numbers are all for 25° C.

TABLE 121.—VISCOSITY OF GASES AND VAPORS.

The values of μ given in the table are 10^6 times the coefficients of viscosity in C. G. S. units.

Substance.	Temp. ° C.	μ.	Reference.	Substance.	Temp. ° C.	μ.	Reference.
Acetone	18.0	78.	1	Chloroform	0.0	95.9	1
Air	-21.4	163.9	2	"	17.4	102.9	"
"	0.0	173.3	"	"	61.2	189.0	3
"	15.0	180.7	"	Ether	0.0	68.9	1
"	99.1	220.3	"	"	16.1	73.2	"
"	182.4	255.9	"	"	36.5	79.3	"
"	302.0	299.3	"	Ethyl iodide	72.3	216.0	3
Alcohol: Methyl	66.8	135.	3	Helium	0.0	189.1	5
" Ethyl	78.4	142.	"	"	15.3	196.9	"
" Propyl, norm.	97.4	142.	"	"	66.6	234.8	"
" Isopropyl	82.8	162.	"	"	184.6	269.9	"
" Butyl, norm.	116.9	143.	"	Hydrogen	-20.6	81.9	2
" Isobutyl	108.4	144.	"	"	15.0	88.9	"
" Tert. butyl	82.9	160.	"	"	99.2	105.9	"
Ammonia	0.0	96.	4	"	182.4	121.5	"
"	20.0	108.	"	"	302.0	139.2	"
Argon	0.0	210.4	5	Mercury	270.0	489.*	8
"	14.7	220.8	"	"	300.0	532.*	"
"	17.9	224.1	"	"	330.0	582.*	"
"	99.7	273.3	"	"	360.0	627.*	"
"	183.7	322.1	"	"	390.0	671.*	"
Benzole	19.0	79.	6	Methane	20.0	120.1	4
"	100.0	118.	"	Methyl iodide	44.0	232.	3
Carbon bisulphide	16.9	92.4	1	" chloride	15.0	105.2	2
" dioxide	-20.7	129.4	2	" "	302.0	213.9	"
" "	15.0	145.7	"	Nitrogen	-21.5	156.3	7
" "	99.1	186.1	"	"	10.9	170.7	"
" "	182.4	222.1	"	"	53.5	189.4	"
" "	302.0	268.2	"	Oxygen	15.4	195.7	"
" monoxide	0.0	163.0	4	"	53.5	215.9	"
" "	20.0	184.0	"	Water vapor	0.0	90.4	1
Chlorine	0.0	128.7	"	" "	16.7	96.7	"
"	20.0	147.0	"	" "	100.0	132.0	9

1 Puluj, Wien. Ber. 69, (2), 1874.
2 Breitenbach, Ann. Phys. 5, 1901.
3 Steudel, Wied. Ann. 16, 1882.
4 Graham, Philos. Trans. Lond. 1846, III.
5 Schultze, Ann. Phys. (4), 5, 6, 1901.
6 Schumann, Wied. Ann. 23, 1884.
7 Obermayer, Wien. Ber. 71, (2a), 1875.
8 Koch, Wied. Ann. 14, 1881, 19, 1883.
9 Meyer-Schumann, Wied. Ann. 13, 1881.

* The values here given were calculated from Koch's table (Wied. Ann. vol. 19, p. 869) by the formula $\mu = 489 [1 + 746 (t-270)]$.

TABLE 122.—VISCOSITY OF AIR. 20.2° C.

Holman, Phil. Mag. 1886	1.810×10^{-4}	Markowski, ditto. 1904	1.835×10^{-4}
Fischer, Phys. Rev. 1909	1.807	Tanzler, Ver. D. Phys. G. 1906	1.836
Grindlay, Gibson, Pr. Roy. Soc. 1908	1.809	Tomlinson, Phil. Trans. 1886	1.811
			1.812
Rankine, ditto. 1910	1.814		1.812
Rapp, unpublished	1.810	Hogg, Am. Acad. Proc. 1905	1.808
Breitenbach, Wied. Ann. 1899	1.833	Gilchrist	1.812
Schultze, Ann. der Phys. 1901	1.837		

The viscosity of air at 20.2° may be taken as 1.812×10^{-4} within a probable error of less than 0.2 per cent. Its variation with the temperature may be obtained from Holman's formula $= 1715.50 \times 10^{-7} (1 + 0.00275t - 0.00000034t^2)$. See Phys. Rev. 1913, p. 124, where full references may be obtained.

TABLE 123.

COEFFICIENT OF VISCOSITY OF GASES.

Temperature Coefficients.

If μ_t = the viscosity at $t°$ C, μ_o = the vicosity at 0°, α = the coefficient of expansion, β, γ, and n = coefficients independent of t, then

(I) $\mu_t = \mu_o(1+\alpha t)^n$. (Meyer, Obermayer, Puluj, Breitenbach.)

(II) $= \mu_o(1+\beta t)$. (Meyer, Obermayer.)

(III) $= \mu_o(1+\alpha t)^{\frac{3}{2}}(1+\gamma t)^2$. (Schumann.)

(IV) $$= \mu_o \frac{1+\frac{C}{273}}{1+\frac{C}{T}} \sqrt{1+\frac{t}{273}}.$$ (Sutherland.)

Gas.	$\mu_o 10^7$.	α.	Constants.	Range ° C.	Reference.
Air *	–	0.003665	$n=0.77$	0–100	1
"	1733.1	.003665	$C=119.4$		2
"	1811.	–	$n=0.7675$	15.0–99.7	3
"	2208.	–	$n=0.7544$	99.7–182.9	"
"	–	–	$n=0.754$; $C=111.3$	–	4
Argon	–	–	$n=0.815$; $C=150.2$	15–100	4
"	2208.	–	$n=0.8227$, $C=169.9$	14.7–99.7	3
"	2733.		$n=0.8119$	99.7–183.7	3
Benzole	698.4	.004	$\gamma=0.00185$	18.7–100	5
Carbon dioxide	1387.9	–	$C=239.7$	–	6
" "	1497.2	.003701	$\gamma=0.000889$	12.8–100	5
" "	1382.1	.003701	$\beta=0.00348$; $n=0.941$	–21.5–53.5	7
" monoxide	1625.2	.003665	$\beta=0.00269$; $n=0.738$	17.5–53.5	"
Ether	689.	.004158	$n=0.94$	0–36.5	8
Ethylene	961.3	–	$C=225.9$	–	6
"	922.2	.003665	$\beta=0.00350$; $n=0.958$	–21.5–53.5	7
" chloride	889.03	.003900	$\beta=0.00381$; $n=0.9772$	15.6–157.3	"
Helium	–	–	$n=0.681$; $C=72.2$	0–15.0	4
"	1969.	–	$n=0.6852$; $C=80.3$	15.3–99.6	3
"	2348.	–	$n=0.6771$	99.6–184.6	3
Hydrogen	857.4	.00366	$C=71.7$	–	2
"	–	–	$n=0.681$; $C=72.2$	–	4
Mercury	1620.	.003665	$n=1.6$	273–380	10
Nitrogen	1658.6	.003665	$\beta=0.00269$; $n=0.738$	–21.5–53.5	7
Nitrous oxide	1353.3	.003719	$\beta=0.00345$; $n=0.929$	–21.5–100.3	"
Oxygen	–	–	$n=0.782$; $C=128.2$	–	4

1 Holman, Proc. Amer. Acad. 12, 1876; 21, 1885; Philos. Mag. (5) 3, 1877; 21, 1886.
2 Breitenbach, Wied. Ann. 5, 1901.
3 Schultze, Ann. Phys. (4) 5, 1901.
4 Rayleigh, Proc. Roy. Soc. 62, 1897; 66, 1900; 67, 1900.
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7 Obermayer, Wien. Ber. 73 (2A), 1876.
8 Puluj, Wien. Ber. 78 (2), 1878.
9 Schultze, Ann Phys. (4) 6, 1901.
10 Koch, Wied. Ann. 19, 1883.

* See Table 122 for viscosity of air.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 124.

DIFFUSION OF AN AQUEOUS SOLUTION INTO PURE WATER.

If k is the coefficient of diffusion, dS the amount of the substance which passes in the time dt, at the place x, through q sq. cm. of a diffusion cylinder under the influence of a drop of concentration dc/dx, then

$$dS = -kq \frac{dc}{dx} dt.$$

k depends on the temperature and the concentration. c gives the gram-molecules per liter. The unit of time is a day.

Substance.	c	t^o	k	Reference	Substance.	c	t^o	k	Reference.
Bromine . . .	0.1	12.	0.8	1	Calcium chloride .	0.864	8.5	0.70	4
Chlorine . . .	"	12.	1.22	"	" " . .	1.22	9.	0.72	"
Copper sulphate .	"	17.	0.39	2	" " . .	0.060	9.	0.64	"
Glycerine . .	"	10.14	0.357	3	" " . .	0.047	9.	0.68	"
Hydrochloric acid .	"	19.2	2.21	2	Copper sulphate .	1.95	17.	0.23	2
Iodine . . .	"	12.	(0.5)	1	" " . .	0.95	17.	0.26	"
Nitric acid . .	"	19.5	2.07	2	" " . .	0.30	17.	0.33	"
Potassium chloride .	"	17.5	1.38	2	" " . .	0.005	17.	0.47	"
" hydrate .	"	13.5	1.72	2	Glycerine . .	2/8	10.14	0.354	3
Silver nitrate . .	"	12.	0.985	2	" . . .	6/8	10.14	0.345	"
Sodium chloride .	"	15.0	0.94	2	" . . .	10/8	10.14	0.329	"
Urea . . .	"	14.8	0.97	3	" . . .	14/8	10.14	0.300	"
Acetic acid . .	0.2	13.5	0.77	4	Hydrochloric acid .	4.52	11.5	2.93	4
Barium chloride .	"	8.	0.66	4	" " .	3.16	11.	2.67	"
Glycerine . .	"	10.1	3.55	3	" " .	0.945	11.	2.12	"
Sodium actetate .	"	12.	0.67	5	" " .	0.387	11.	2.02	"
" chloride .	"	15.0	0.94	2	" " .	0.250	11.	1.84	"
Urea . . .	"	14.8	0.969	3	Magnesium sulphate	2.18	5.5	0.28	4
Acetic acid . .	1.0	12.	0.74	6	" " .	0.541	5.5	0.32	"
Ammonia . .	"	15.23	1.54	7	" " .	3.23	10.	0.27	"
Formic acid . .	"	12.	0.97	7	" " .	0.402	10.	0.34	"
Glycerine . .	"	10.14	0.339	3	Potassium hydrate .	0.75	12.	1.72	6
Hydrochloric acid .	"	12.	2.09	6	" " .	0.49	12.	1.70	"
Magnesium sulphate	"	7.	0.30	4	" " .	0.375	12.	1.70	"
Potassium bromide .	"	10.	1.13	8	" nitrate .	3.9	17.6	0.89	2
" hydrate .	"	12.	1.72	6	" " .	1.4	17.6	1.10	"
Sodium chloride .	"	15.0	0.94	2	" " .	0.3	17.6	1.26	"
" " . .	"	14.3	0.964	3	" " .	0.02	17.6	1.28	"
" hydrate .	"	12.	1.11	2	" sulphate	0.95	19.6	0.79	"
" iodide .	"	10.	0.80	8	" " .	0.28	19.6	0.86	"
Sugar . . .	"	12.	0.254	6	" " .	0.05	19.6	0.97	"
Sulphuric acid .	"	12.	1.12	6	" " .	0.02	19.6	1.01	"
Zinc sulphate . .	"	14.8	0.236	9	Silver nitrate . .	3.9	12.	0.535	"
Acetic acid . .	2.0	12.	0.69	6	" " . .	0.9	12.	0.88	"
Calcium chloride .	"	10.	0.68	8	" " . .	0.02	12.	1.035	"
Cadmium sulphate .	"	19.04	0.246	9	Sodium chloride .	2/8	14.33	1.013	3
Hydrochloric acid .	"	12.	2.21	6	" " . .	4/8	14.33	0.996	"
Sodium iodide .	"	10.	0.90	8	" " . .	6/8	14.33	0.980	2
Sulphuric acid .	"	12.	1.16	6	" " . .	10/8	14.33	0.948	"
Zinc acetate . .	"	18.05	0.210	9	" " . .	14/8	14.33	0.917	"
" " . .	"	0.04	0.120	9	Sulphuric acid .	9.85	18.	2.36	2
Acetic acid . .	3.0	12.	0.68	–	" " . .	4.85	18.	1.90	"
Potassium carbonate	"	10.	0.60	8	" " . .	2.85	18.	1.60	"
" hydrate .	"	12.	1.89	6	" " . .	0.85	18.	1.34	"
Acetic acid . .	4.0	12.	0.66	6	" " . .	0.35	18.	1.32	"
Potassium chloride .	"	10.	1.27	8	" " . .	0.005	18.	1.30	"

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8 Schuhmeister, Wien. Ber. 79 (2), 1879.
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Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

Table 125.

DIFFUSION OF VAPORS.

Coefficients of diffusion of vapors in C. G. S. units. The coefficients are for the temperatures given in the table and a pressure of 76 centimeters of mercury.*

Vapor.	Temp. C. °	k_t for vapor diffusing into hydrogen.	k_t for vapor diffusing into air.	k_t for vapor diffusing into carbon dioxide.
Acids: Formic	0.0	0.5131	0.1315	0.0879
"	65.4	0.7873	0.2035	0.1343
"	84.9	0.8830	0.2244	0.1519
Acetic	0.0	0.4040	0.1061	0.0713
"	65.5	0.6211	0.1578	0.1048
"	98.5	0.7481	0.1965	0.1321
Isovaleric	0.0	0.2118	0.0555	0.0375
"	98.0	0.3934	0.1031	0.0696
Alcohols: Methyl	0.0	0.5001	0.1325	0.0880
"	25.6	0.6015	0.1620	0.1046
"	49.6	0.6738	0.1809	0.1234
Ethyl	0.0	0.3806	0.0994	0.0693
"	40.4	0.5030	0.1372	0.0898
"	66.9	0.5430	0.1475	0.1026
Propyl	0.0	0.3153	0.0803	0.0577
"	66.9	0.4832	0.1237	0.0901
"	83.5	0.5434	0.1379	0.0976
Butyl	0.0	0.2716	0.0681	0.0476
"	99.0	0.5045	0.1265	0.0884
Amyl	0.0	0.2351	0.0589	0.0422
"	99.1	0.4362	0.1094	0.0784
Hexyl	0.0	0.1998	0.0499	0.0351
"	99.0	0.3712	0.0927	0.0651
Benzene	0.0	0.2940	0.0751	0.0527
"	19.9	0.3409	0.0877	0.0609
"	45.0	0.3993	0.1011	0.0715
Carbon disulphide	0.0	0.3690	0.0883	0.0629
" "	19.9	0.4255	0.1015	0.0726
" "	32.8	0.4626	0.1120	0.0789
Esters: Methyl acetate	0.0	0.3277	0.0840	0.0557
" "	20.3	0.3928	0.1013	0.0679
Ethyl "	0.0	0.2373	0.0630	0.0450
" "	46.1	0.3729	0.0970	0.0666
Methyl butyrate	0.0	0.2422	0.0640	0.0438
" "	92.1	0.4308	0.1139	0.0809
Ethyl "	0.0	0.2238	0.0573	0.0406
" "	96.5	0.4112	0.1064	0.0756
" valerate	0.0	0.2050	0.0505	0.0366
" "	97.6	0.3784	0.0932	0.0676
Ether	0.0	0.2960	0.0775	0.0552
"	19.9	0.3410	0.0893	0.0636
Water	0.0	0.6870	0.1980	0.1310
"	49.5	1.0000	0.2827	0.1811
"	92.4	1.1794	0.3451	0.2384

* Taken from Winkelmann's papers (Wied. Ann. vols. 22, 23, and 26). The coefficients for 0° were calculated by Winkelmann on the assumption that the rate of diffusion is proportional to the absolute temperature. According to the investigations of Loschmidt and of Obermeyer the coefficient of diffusion of a gas, or vapor, at 0° C. and a pressure of 76 centimetres of mercury may be calculated from the observed coefficient at another temperature and pressure by the formula $k_0 = k_T \left(\frac{T_0}{T}\right)^n \frac{76}{p}$, where T is temperature absolute and p the pressure of the gas. The exponent n is found to be about 1.75 for the permanent gases and about 2 for condensible gases. The following are examples: Air — CO_2, $n = 1.968$; CO_2 — N_2O, $n = 2.05$; CO_2 — H, $n = 1.742$; CO — O, $n = 1.785$; H — O, $n = 1.755$; O — N, $n = 1.792$. Winkelmann's results, as given in the above table, seem to give about 2 for vapors diffusing into air, hydrogen or carbon dioxide.

DIFFUSION OF GASES, VAPORS, AND METALS.

TABLE 126. — Coefficients of Diffusion for Various Gases and Vapors.*

Gas or Vapor diffusing.	Gas or Vapor diffused into.	Temp. ° C.	Coefficient of Diffusion.	Authority.
Air	Hydrogen	0	0.661	Schulze.
"	Oxygen	0	0.1775	Obermayer.
Carbon dioxide	Air	0	0.1423	Loschmidt.
" "	"	0	0.1360	Waitz.
" "	Carbon monoxide	0	0.1405	Loschmidt.
" "	" "	0	0.1314	Obermayer.
" "	Hydrogen	0	0.5437	"
" "	Methane	0	0.1465	"
" "	Nitrous oxide	0	0.0983	Loschmidt.
" "	Oxygen	0	0.1802	"
Carbon disulphide	Air	0	0.0995	Stefan.
Carbon monoxide	Carbon dioxide	0	0.1314	Obermayer.
" "	Ethylene	0	0.101	"
" "	Hydrogen	0	0.6422	Loschmidt.
" "	Oxygen	0	0.1802	"
" "	"	0	0.1872	Obermayer.
Ether	Air	0	0.0827	Stefan.
"	Hydrogen	0	0.3054	"
Hydrogen	Air	0	0.6340	Obermayer.
"	Carbon dioxide	0	0.5384	"
"	" monoxide	0	0.6488	"
"	Ethane	0	0.4593	"
"	Ethylene	0	0.4863	"
"	Methane	0	0.6254	"
"	Nitrous oxide	0	0.5347	"
"	Oxygen	0	0.6788	"
Nitrogen	"	0	0.1787	"
Oxygen	Carbon dioxide	0	0.1357	"
"	Hydrogen	0	0.7217	Loschmidt.
"	Nitrogen	0	0.1710	Obermayer.
Sulphur dioxide	Hydrogen	0	0.4828	Loschmidt.
Water	Air	8	0.2390	Guglilemo.
"	"	18	0.2475	"
"	Hydrogen	18	0.8710	"

* Compiled for the most part from a similar table in Landolt & Börnstein's Phys. Chem. Tab.

TABLE 127. — Diffusion of Metals into Metals.

$\frac{dv}{dt} = k\frac{d^2v}{dx^2}$; where x is the distance in direction of diffusion; v, the degree of concentration of the diffusing metal; t, the time; k, the diffusion constant = the quantity of metal in grams diffusing through a sq. cm. in a day when unit difference of concentration (gr. per cu. cm.) is maintained between two sides of a layer one cm. thick.

Diffusing Metal.	Dissolving Metal.	Temperature ° C.	k.	Diffusing Metal.	Dissolving Metal.	Temperature ° C.	k.
Gold	Lead	555	3.19	Platinum	Lead	492	1.69
"	"	492	3.00	Lead	Tin	555	3.18
"	"	251	0.03	Rhodium	Lead	550	3.04
"	"	200	0.008	Tin	Mercury	15	1.22*
"	"	165	0.004	Lead	"	15	1.0*
"	"	100	0.00002	Zinc	"	15	1.0*
"	Bismuth	555	4.52	Sodium	"	15	0.45*
"	Tin	555	4.65	Potassium	"	15	0.40*
Silver	"	555	4.14	Gold	"	15	0.72*

From Roberts-Austen, Philosophical Transactions, 187A, p. 383, 1896.
* These values are from Guthrie.

Table 128.

SOLUBILITY OF INORGANIC SALTS IN WATER; VARIATION WITH THE TEMPERATURE.

The numbers give the number of grams of the *anhydrous* salt soluble in 1000 grams of water at the given temperatures.

Salt.	Temperature Centigrade.										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
$AgNO_3$	1150	1600	2150	2700	3350	4000	4700	5500	6500	7600	9100
$Al_2(SO_4)_3$	313	335	362	404	457	521	591	662	731	808	891
$Al_2K_2(SO_4)_4$	30	–	–	84	–	–	248	–	–	–	1540
$Al_2(NH_4)_2(SO_4)_4$	26	45	66	91	124	159	211	270	352	–	–
B_2O_3	11	15	22	–	40	–	62	–	95	–	157
$BaCl_2$	316	333	357	382	408	436	464	494	524	556	588
$Ba(NO_3)_2$	50	70	92	116	142	171	203	236	270	306	342
$CaCl_2$	595	650	745	1010	1153	–	1368	1417	1470	1527	1590
$CoCl_2$	405	450	500	565	650	935	940	950	960	–	1030
$CsCl$	1614	1747	1865	1973	2080	2185	2290	2395	2500	2601	2705
$CsNO_3$	93	149	230	339	472	644	838	1070	1340	1630	1970
Cs_2SO_4	1671	1731	1787	1841	1899	1949	1999	2050	2103	2149	2203
$Cu(NO_3)_2$	818	–	1250	–	1598	–	1791	–	2078	–	
$CuSO_4$	149	–	–	255	295	336	390	457	535	627	735
$FeCl_2$	–	–	685	–	–	820	–	–	1040	1050	1060
Fe_2Cl_6	744	819	918	–	–	3151	–	–	5258	–	5357
$FeSO_4$	156	208	264	330	402	486	550	560	506	430	–
$HgCl_2$	43	66	74	84	96	113	139	173	243	371	540
KBr	540	–	650	–	760	–	860	–	955	–	1050
K_2CO_3	1050	–	–	1140	1170	1210	1270	1330	1400	1470	1560
KCl	285	312	343	373	401	429	455	483	510	538	566
$KClO_3$	33	50	71	101	145	197	260	325	396	475	560
K_2CrO_4	589	609	629	650	670	690	710	730	751	771	791
$K_2Cr_2O_7$	50	85	131	–	292	–	505	–	730	–	1020
$KHCO_3$	225	277	332	390	453	522	600	–	–	–	–
KI	1279	1361	1442	1523	1600	1680	1760	1840	1920	2010	2090
KNO_3	133	209	316	458	639	855	1099	1380	1690	2040	2460
KOH	970	1030	1120	1260	1360	1400	1460	1510	1590	1680	1780
K_2PtCl_6	7	9	11	14	18	22	26	32	38	45	52
K_2SO_4	74	92	111	130	148	165	182	198	214	228	241
$LiOH$	127	127	128	129	130	133	138	144	153	–	175
$MgCl_2$	528	535	545		575	–	610	·	660	–	730
$MgSO_4$ (7aq)	260	309	356	409	456	–	–	–	–	–	–
" (6aq)	408	422	439	453	–	504	550	596	642	689	738
NH_4Cl	297	333	372	414	458	504	552	602	656	713	773
NH_4HCO_3	119	159	210	270	–	–	–	–	–	–	–
NH_4NO_3	1183	–	–	2418	2970	3540?	4300?	5130?	5800	7400	8710
$(NH_4)_2SO_4$	706	730	754	780	810	844	880	916	953	992	1033
$NaBr$	795	845	903	–	1058	1160	1170	–	1185	–	1205
$Na_2B_4O_7$	–	16	–	39	–	105	200	244	314	408	523
Na_2CO_3 (10aq)	71	126	214	409	–	–	–	–	–	–	–
" (7aq)	204	263	335	435	(1aq)	475	464	458	452	452	452
$NaCl$	356	357	358	360	363	367	371	375	380	385	391
$NaClO_3$	820	890	990	–	1235	–	1470	–	1750	–	2040
Na_2CrO_4	317	502	900	–	960	1050	1150	–	1240	–	1260
$Na_2Cr_2O_7$	1630	1700	1800	1970	2200	2480	2830	3230	3860	–	4330
$NaHCO_3$	69	82	96	111	127	145	164	–	–	–	–
Na_2HPO_4	25	39	93	241	639	–	–	949	–	–	988
NaI	1590	1690	1790	1900	2050	2280	2570	–	2950	–	3020
$NaNO_3$	730	805	880	962	1049	1140	1246	1360	1480	1610	1755

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

SOLUBILITY OF SALTS AND GASES IN WATER.

TABLE 128 (*concluded*) — **Solubility of Inorganic Salts in Water; Variation with the Temperature.**

The numbers give the number of grams of the *anhydrous* salt soluble in 1000 grams of water at the given temperatures.

Salt.	Temperature Centigrade.										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
$NaOH$	420	515	1090	1190	1290	1450	1740	–	3130	–	–
$Na_4P_2O_7$	32	39	62	99	135	174	220	255	300	–	–
Na_2SO_3	141	–	287	–	495	–	–	–	–	–	330
Na_2SO_4 (10aq)	50	90	194	400	482	468	455	445	437	429	427
" (7aq)	196	305	447	–							
$Na_2S_2O_3$	525	610	700	847	1026	1697	2067	–	2488	2542	2660
$NiCl_2$	–	600	640	680	720	760	810	–	–	–	–
$NiSO_4$	272	–	–	425	–	502	548	594	632	688	776
$PbBr_2$	5	6	8	12	15	20	24	28	33	–	48
$Pb(NO_3)_2$	365	444	523	607	694	787	880	977	1076	1174	1270
$RbCl$	770	844	911	976	1035	1093	1155	1214	1272	1331	1389
$RbNO_3$	195	330	533	813	1167	1556	2000	2510	3090	3750	4520
Rb_2SO_4	364	426	482	535	585	631	674	714	750	787	818
$SrCl_2$	442	483	539	600	667	744	831	896	924	962	1019
SnI_2	–	–	10	12	14	17	21	25	30	34	40
$Sr(NO_3)_2$	395	549	708	876	913	926	940	956	972	990	1011
$Th(SO_4)_2$ (9aq)	7	10	14	20	30	51	–	–	–	–	–
" (4aq)	–	–	–	–	40	25	16	11	–		–
$TlCl$	2	2	3	5	6	8	10	13	16	20	–
$TlNO_3$	39	62	96	143	209	304	462	695	1110	2000	4140
Tl_2SO_4	27	37	49	62	76	92	109	127	146	165	–
$Yb_2(SO_4)_3$	442	–	–	–	–	–	104	72	69	58	47
$Zn(NO_3)_2$	948	–		–	2069	–	–	–	–	–	–
$ZnSO_4$	–	–	–	–	700	768	–	890	860	920	785

TABLE 129. — **Solubility of a Few Organic Salts in Water; Variation with the Temperature.**

Salt.	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
$H_2(CO_2)_2$	36	53	102	159	228	321	445	635	978	1200	–
$H_2(CH_2.CO_2)_2$	28	45	69	106	162	244	358	511	708	–	1209
Tartaric acid	1150	1260	1390	1560	1760	1950	2180	2440	2730	3070	3430
Racemic "	92	140	206	291	433	595	783	999	1250	1530	1850
$K(HCO_2)$	2900	–	3350	–	3810	–	4550	–	5750	–	7900
$KH(C_4H_4O_4)$	3	4	6	9	13	18	24	32	45	57	69

TABLE 130. — **Solubility of Gases in Water; Variation with the Temperature.**

The table gives the weight in grams of the gas which will be absorbed in 1000 grams of water when the partial pressure of the gas plus the vapor pressure of the liquid at the given temperature equals 760 mm.

Gas.	0°	10°	20°	30°	40°	50°	60°	70°	80°
O_2	.0705	.0551	.0443	.0368	.0311	.0263	.0221	.0181	.0135
H_2	.00192	.00174	.00160	.00147	.00138	.00129	.00118	.00102	.00079
N_2	.0293	.0230	.0189	.0161	.0139	.0121	.0105	.0089	.0069
Br_2	431.	248.	148.	94.	62.	40.	28.	18.	11.
Cl_2	–	9.97	7.29	5.72	4.59	3.93	3.30	2.79	2.23
CO_2	3.35	2.32	1.69	1.26	0.97	0.76	0.58	–	–
H_2S	7.10	5.30	3.98	–	–	–	–	–	–
NH_3	987.	689.	535.	422.	–	–	–	–	–
SO_2	228.	162.	113.	78.	54.	–	–	–	–

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

Table 131.

CHANGE OF SOLUBILITY PRODUCED BY UNIFORM PRESSURE.*

Pressure in atmospheres.	$CdSO_4 8/3 H_2O$ at 25°		$ZnSO_4 . 7H_2O$ at 25°		Mannite at 24.05°		NaCl at 24.05°	
	Conc. of satd. soln. gs. $CdSO_4$ per 100 gs. H_2O	Percentage change.	Conc. of satd. soln. gs. $ZnSO_4$ per 100 gs. H_2O.	Percentage change.	Conc. of satd. soln. gs. mannite per 100 gs. H_2O.	Percentage change.	Conc. of satd. soln. gs. NaCl. per 100 gs. H_2O.	Percentage change.
1	76.80	—	57.95	—	20.66	—	35.90	—
500	78.01	+1.57	57.87	−0.14	21.14	+2.32	36.55	+1.81
1000	78.84	+2.68	57.65	−0.52	21.40	+3.57	37.02	+3.12
1500	—	—	—	—	21.64	+4.72	37.36	+4.07

* E. Cohen and L. R. Sinnige, *Z. physik. Chem.* 67, p. 432, 1909; 69, p. 102, 1909. E. Cohen, K. Inouye and C. Euwen, *ibid.* 75, p. 257, 1911. These authors give a critical résumé of earlier work along this line.

ABSORPTION OF GASES BY LIQUIDS.*

Temperature Centigrade. t	Absorption Coefficients, a_t, for Gases in Water.						
	Carbon dioxide. CO_2	Carbon monoxide. CO	Hydrogen. H	Nitrogen. N	Nitric oxide. NO	Nitrous oxide. N_2O	Oxygen. O
0	1.797	0.0354	0.02110	0.02399	0.0738	1.048	0.04925
5	1.450	.0315	.02022	.02134	.0646	0.8778	.04335
10	1.185	.0282	.01944	.01918	.0571	0.7377	.03852
15	1.002	.0254	.01875	.01742	.0515	0.6294	.03456
20	0.901	.0232	.01809	.01599	.0471	0.5443	.03137
25	0.772	.0214	.01745	.01481	.0432	–	.02874
30	–	.0200	.01690	.01370	.0400	–	.02646
40	0.506	.0177	.01644	.01195	.0351	–	.02316
50	–	.0161	.01608	.01074	.0315	–	.02080
100	0.244	.0141	.01600	.01011	.0263	–	.01690

Temperature Centigrade. t	Air.	Ammonia. NH_3	Chlorine. Cl	Ethylene. C_2H_4	Methane. CH_4	Hydrogen sulphide. H_2S	Sulphur dioxide. SO_2
0	0.02471	1174.6	3.036	0.2563	0.05473	4.371	79.79
5	.02179	971.5	2.808	.2153	.04889	3.965	67.48
10	.01953	840.2	2.585	.1837	.04367	3.586	56.65
15	.01795	756.0	2.388	.1615	.03903	3.233	47.28
20	.01704	683.1	2.156	.1488	.03499	2.905	39.37
25	–	610.8	1.950	–	.02542	2.604	32.79

Temperature Centigrade. t	Absorption Coefficients, a_t, for Gases in Alcohol, C_2H_5OH.								
	Carbon dioxide. CO_2	Ethylene. C_2H_4	Methane. CH_4	Hydrogen. H	Nitrogen. N	Nitric oxide. NO	Nitrous oxide. N_2O	Hydrogen sulphide. H_2S	Sulphur dioxide. SO_2
0	4.329	3.595	0.5226	0.0692	0.1263	0.3161	4.190	17.89	328.6
5	3.891	3.323	.5086	.0685	.1241	.2998	3.838	14.78	251.7
10	3.514	3.086	.4953	.0679	.1228	.2861	3.525	11.99	190.3
15	3.199	2.882	.4828	.0673	.1214	.2748	3.215	9.54	144.5
20	2.946	2.713	.4710	.0667	.1204	.2659	3.015	7.41	114.5
25	2.756	2.578	.4598	.0662	.1196	.2595	2.819	5.62	99.8

* This table contains the volumes of different gases, supposed measured at 0° C. and 76 centimeters' pressure, which unit volume of the liquid named will absorb at atmospheric pressure and the temperature stated in the first column. The numbers tabulated are commonly called the absorption coefficients for the gases in water, or in alcohol, at the temperature t and under one atmosphere of pressure. The table has been compiled from data published by Bohr & Bock, Bunsen, Carius, Dittmar, Hamberg, Henrick, Pagliano & Emo, Raoult, Schöofeld, Setschenow, and Winkler. The numbers are in many cases averages from several of these authorities.

NOTE. — The effect of increase of pressure is generally to increase the absorption coefficient. The following is approximately the magnitude of the effect in the case of ammonia in alcohol at a temperature of 23° C.:

P =	45 cms.	50 cms.	55 cms.	60 cms.	65 cms.
a_{23} =	69	74	79	84	88

According to Setschenow the effect of varying the pressure from 45 to 85 centimeters in the case of carbonic acid in water is very small.

CAPILLARITY.—SURFACE TENSION OF LIQUIDS.*

TABLE 133.—Water and Alcohol in Contact with Air.

Temp. C.	Surface tension in dynes per centimeter. Water.	Ethyl alcohol.	Temp. C.	Surface tension in dynes per centimeter. Water.	Ethyl alcohol.	Temp. C.	Surface tension in dynes per centimeter. Water.
0°	75.6	23.5	40°	70.0	20.0	80°	64.3
5	74.9	23.1	45	69.3	19.5	85	63.6
10	74.2	22.6	50	68.6	19.1	90	62.9
15	73.5	22.2	55	67.8	18.6	95	62.2
20	72.8	21.7	60	67.1	18.2	100	61.5
25	72.1	21.3	65	66.4	17.8	–	–
30	71.4	20.8	70	65.7	17.3	–	–
35	70.7	20.4	75	65.0	16.9	–	–

TABLE 134.—Miscellaneous Liquids in Contact with Air.

Liquid.	Temp. C.°	Surface tension in dynes per centimeter.	Authority.
Aceton	16.8	23.3	Ramsay-Shields.
Acetic acid	17.0	30.2	Average of various.
Amyl alcohol	15.0	24.8	"
Benzole	15.0	28.8	"
Butyric acid	15.0	28.7	"
Carbon disulphide	20.0	30.5	Quincke.
Chloroform	20.0	28.3	Average of various.
Ether	20.0	18.4	"
Glycerine	17.0	63.14	Hall.
Hexane	0.0	21.2	Schiff.
"	68.0	14.2	"
Mercury	18.0	520.0	Average of various.
Methyl alcohol	15.0	24.7	"
Olive oil	20.0	34.7	"
Petroleum	20.0	25.9	Magie.
Propyl alcohol	5.8	25.9	Schiff.
" "	97.1	18.0	"
Toluol	15.0	29.1	"
"	109.8	18.9	"
Turpentine	21.0	28.5	Average of various.

TABLE 135.—Solutions of Salts in Water.†

Salt in solution.	Density.	Temp. C.°	Tension in dynes per cm.
$BaCl_2$	1.2820	15–16	81.8
"	1.0497	15–16	77.5
$CaCl_2$	1.3511	19	95.0
"	1.2773	19	90.2
HCl	1.1190	20	73.6
"	1.0887	20	74.5
"	1.0242	20	75.3
KCl	1.1699	15–16	82.8
"	1.1011	15–16	80.1
"	1.0463	15–16	78.2
$MgCl_2$	1.2338	15–16	90.1
"	1.1694	15–16	85.2
"	1.0362	15–16	78.0
$NaCl$	1.1932	20	85.8
"	1.1074	20	80.5
"	1.0360	20	77.6
NH_4Cl	1.0758	16	84.3
"	1.0535	16	81.7
"	1.0281	16	78.8
$SrCl_2$	1.3114	15–16	85.6
"	1.1204	15–16	79.4
"	1.0567	15–16	77.8
K_2CO_3	1.3575	15–16	90.9
"	1.1576	15–16	81.8
"	1.0400	15–16	77.5
Na_2CO_3	1.1329	14–15	79.3
"	1.0605	14–15	77.8
"	1.0283	14–15	77.2
KNO_3	1.1263	14	78.9
"	1.0466	14	77.6
$NaNO_3$	1.3022	12	83.5
"	1.1311	12	80.0
$CuSO_4$	1.1775	15–16	78.6
"	1.0276	15–16	77.0
H_2SO_4	1.8278	15	63.0?
"	1.4453	15	79.7
"	1.2636	15	79.7
K_2SO_4	1.0744	15–16	78.0
"	1.0360	15–16	77.4
$MgSO_4$	1.2744	15–16	83.2
"	1.0680	15–16	77.8
Mn_2SO_4	1.1119	15–16	79.1
"	1.0329	15–16	77.3
$ZnSO_4$	1.3981	15–16	83.3
"	1.2830	15–16	80.7
"	1.1039	15–16	77.8

* This determination of the capillary constants of liquids has been the subject of many careful experiments, but the results of the different experimenters, and even of the same observer when the method of measurement is changed, do not agree well together. The values here quoted can only be taken as approximations to the actual values for the liquids in a state of purity in contact with pure air. In the case of water the values given by Lord Rayleigh from the wave length of ripples (Phil. Mag. 1890) and by Hall from direct measurement of the tension of a flat film (Phil. Mag. 1893) have been preferred, and the temperature correction has been taken as 0.141 dyne per degree centigrade. The values for alcohol were derived from the experiments of Hall above referred to and the experiments on the effect of temperature made by Timberg (Wied. Ann. vol. 30).

The authority for a few of the other values given is quoted, but they are for the most part average values derived from a large number of results published by different experimenters.

† From Volkmann (Wied. Ann. vol. 17, p. 353).

TENSION OF LIQUIDS.

TABLE 136. — Surface Tension of Liquids.*

Liquid.	Specific gravity.	Surface tension in dynes per centimeter of liquid in contact with — Air.	Water.	Mercury.
Water	1.0	75.0	0.0	(392)
Mercury	13.543	513.0	392.0	0
Bisulphide of carbon	1.2687	30.5	41.7	(387)
Chloroform	1.4878	(31.8)	26.8	(415)
Ethyl alcohol	0.7906	(24.1)	–	364
Olive oil	0.9136	34.6	18.6	317
Turpentine	0.8867	28.8	11.5	241
Petroleum	.7977	29.7	(28.9)	271
Hydrochloric acid	1.10	(72.9)	–	(392)
Hyposulphite of soda solution	1.1248	69.9	–	429

TABLE 137. — Surface Tension of Liquids at Solidifying Point.†

Substance.	Temperature of solidification. Cent.°	Surface tension in dynes per centimeter.	Substance.	Temperature of solidification. Cent.°	Surface tension in dynes per centimeter.
Platinum	2000	1691	Antimony	432	249
Gold	1200	1003	Borax	1000	216
Zinc	360	877	Carbonate of soda	1000	210
Tin	230	599	Chloride of sodium	–	116
Mercury	—40	588	Water	0	87.9‡
Lead	330	457	Selenium	217	71.8
Silver	1000	427	Sulphur	111	42.1
Bismuth	265	1390	Phosphorus	43	42.0
Potassium	58	371	Wax	68	34.1
Sodium	90	258			

TABLE 138. — Tension of Soap Films.

Elaborate measurements of the thickness of soap films have been made by Reinold and Rucker.|| They find that a film of oleate of soda solution containing 1 of soap to 70 of water, and having 3 per cent of KNO_3 added to increase electrical conductivity, breaks at a thickness varying between 7.2 and 14.5 micro-millimeters, the average being 12.1 micro-millimeters. The film becomes black and apparently of nearly uniform thickness round the point where fracture begins. Outside the black patch there is the usual display of colors, and the thickness at these parts may be estimated from the colors of thin plates and the refractive index of the solution (*vide* Newton's rings, Table 222).

When the percentage of KNO_3 is diminished, the thickness of the black patch increases. For example,

KNO_3 =	3	1	0.5	0.0
Thickness =	12.4	13.5	14.5	22.1 micro-mm.

A similar variation was found in the other soaps.

It was also found that diminishing the proportion of soap in the solution, there being no KNO_3 dissolved, increased the thickness of the film.

1 part soap to 30 of water gave thickness 21.6 micro-mm.
1 part soap to 40 of water gave thickness 22.1 micro-mm.
1 part soap to 60 of water gave thickness 27.7 micro-mm.
1 part soap to 80 of water gave thickness 29.3 micro-mm.

* This table of tensions at the surface separating the liquid named in the first column and air, water or mercury as stated at the head of the last three columns, is from Quincke's experiments (Pogg. Ann. vol. 139, and Phil. Mag. 1871). The numbers given are the equivalent in dynes per centimeter of those obtained by Worthington from Quincke's results (Phil. Mag. vol. 20, 1885) with the exception of those in brackets, which were not corrected by Worthington; they are probably somewhat too high, for the reason stated by Worthington. The temperature was about 20° C.

† Quincke, "Pogg. Ann." vol. 135, p. 661.

‡ It will be observed that the value here given on the authority of Quincke is much higher than his subsequent measurements, as quoted above, give.

|| "Proc. Roy. Soc." 1877, and "Phil. Trans. Roy. Soc." 1881, 1883, and 1893.

NOTE. — Quincke points out that substances may be divided into groups in each of which the ratio of the surface tension to the density is nearly constant. Thus, if this ratio for mercury be taken as unit, the ratio for the bromides and iodides is about a half: that of the nitrates, chlorides, sugars, and fats, as well as the metals, lead, bismuth, and antimony, about 1; that of water, the carbonates, sulphates, and probably phosphates, and the metals platinum, gold, silver, cadmium, tin, and copper, 2; that of zinc, iron, and palladium, 3; and that of sodium, 6.

VAPOR PRESSURES.

The vapor pressures here tabulated have been taken, with one exception, from Regnault's results. The vapor pressure of Pictet's fluid is given on his own authority. The pressures are in centimeters of mercury.

Temperature Cent.	Acetone. C_3H_6O	Benzol. C_6H_6	Carbon bisulphide. CS_2	Carbon tetrachloride. CCl_4	Chloroform. $CHCl_3$	Ethyl alcohol. C_2H_6O	Ethyl ether. $C_4H_{10}O$	Ethyl bromide. C_2H_5Br	Methyl alcohol. CH_4O	Turpentine. $C_{10}H_6$
—25°	-	-	-	-	-	-	-	4.41	.41	-
—20	-	.58	4.73	.98	-	.33	6.89	5.92	.63	-
—15	-	.88	6.16	1.35	-	.51	8.93	7.81	.93	-
—10	-	1.29	7.94	1.85	-	.65	11.47	10.15	1.35	-
—5	-	1.83	10.13	2.48	-	.91	14.61	13.06	1.92	-
0	-	2.53	12.79	3.29	5.97	1.27	18.44	16.56	2.68	.21
5	-	3.42	16.00	4.32	-	1.76	23.09	20.72	3.69	-
10	-	4.52	19.85	5.60	10.05	2.42	28.68	25.74	5.01	.29
15	-	5.89	24.41	7.17	-	3.30	35.36	31.69	6.71	-
20	17.96	7.56	29.80	9.10	16.05	4.45	43.28	38.70	8.87	.44
25	22.63	9.59	36.11	11.43	20.02	5.94	52.59	46.91	11.60	-
30	28.10	12.02	43.46	14.23	24.75	7.85	63.48	56.45	15.00	.69
35	34.52	14.93	51.97	17.55	30.35	10.29	76.12	67.49	19.20	-
40	42.01	18.36	61.75	21.48	36.93	13.37	90.70	80.19	24.35	1.08
45	50.75	22.41	72.95	26.08	44.60	17.22	107.42	94.73	30.61	-
50	62.29	27.14	85.71	31.44	53.50	21.99	126.48	111.28	38.17	1.70
55	72.59	32.64	100.16	37.63	63.77	27.86	148.11	130.03	47.22	-
60	86.05	39.01	116.45	44.74	75.54	35.02	172.50	151.19	57.99	2.65
65	101.43	46.34	134.75	52.87	88.97	43.69	199.89	174.95	70.73	-
70	118.94	54.74	155.21	62.11	104.21	54.11	230.49	201.51	85.71	4.06
75	138.76	64.32	177.99	72.57	121.42	66.55	264.54	231.07	103.21	-
80	161.10	75.19	203.25	84.33	140.76	81.29	302.28	263.86	123.85	6.13
85	186.18	87.46	231.17	97.51	162.41	98.64	343.95	300.06	147.09	-
90	214.17	101.27	261.91	112.23	186.52	118.93	389.83	339.89	174.17	9.06
95	245.28	116.75	296.63	128.69	213.28	142.51	440.18	383.55	205.17	-
100	279.73	134.01	332.51	146.71	242.85	169.75	495.33	431.23	240.51	13.11
105	317.70	153.18	372.72	166.72	275.40	201.04	555.62	483.12	280.63	-
110	359.40	174.44	416.41	188.74	311.10	236.76	621.46	539.40	325.96	18.60
115	405.00	197.82	463.74	212.91	350.10	277.34	693.33	600.24	376.98	
120	454.69	223.54	514.88	239.37	392.57	323.17	771.92	665.80	434.18	25.70
125	508.62	251.71	569.97	268.24	438.66	374.69	-	736.22	498.05	-
130	566.97	282.43	629.16	299.69	488.51	432.30	-	811.65	569.13	34.90
135	629.87	315.85	692.59	333.86	542.25	496.42	-	892.19	647.93	-
140	697.44	352.07	760.40	370.90	600.02	567.46	-	977.96	733.71	46.40
145	-	391.21	832.69	411.00	661.92	645.80	-	-	830.89	-
150	-	433.37	909.59	454.31	728.06	731.84	-	-	936.13	60.50
155	-	478.65	-	501.02	798.53	825.92	-	-	-	68.60
160	-	527.14	-	551.31	873.42	-	-	-	-	77.50
165	-	568.30	-	605.38	952.78	-	-	-	-	-
170	-	634.07	-	663.44	-	-	-	-	-	-

VAPOR PRESSURES.

Temperature, Centigrade.	Ammonia. NH_3	Carbon dioxide. CO_2	Ethyl chloride. C_2H_5Cl	Ethyl iodide. C_2H_5I	Methyl chloride. CH_3Cl	Methylic ether. C_2H_6O	Nitrous oxide. N_2O	Pictet's fluid. $64SO_2+44CO_2$ by weight	Sulphur dioxide. SO_2	Hydrogen sulphide. H_2S
−30°	86.61	-	11.02	-	57.90	57.65		58.52	28.75	-
−25	110.43	1300.70	14.50	-	71.78	71.61	1569.49	67.64	37.38	374.93
−20	139.21	1514.24	18.75	-	88.32	88.20	1758.66	74.48	47.95	443.85
−15	173.65	1758.25	23.96	-	107.92	107.77	1968.43	89.68	60.79	519.65
−10	214.46	2034.02	30.21	-	130.96	130.66	2200.80	101.84	76.25	608.46
−5	264.42	2344.13	37.67	-	157.87	157.25	2457.92	121.60	94.69	706.60
0	318.33	2690.66	46.52	4.19	189.10	187.90	2742.10	139.08	116.51	820.63
5	383.03	3075.38	56.93	5.41	225.11	222.90	3055.86	167.20	142.11	949.08
10	457.40	3499.86	61.11	6.92	266.38	262.90	3401.91	193.80	171.95	1089.63
15	543.34	3964.69	83.26	8.76	313.41	307.98	3783.17	226.48	206.49	1244.79
20	638.78	4471.66	99.62	11.00	366.69	358.60	4202.79	258.40	246.20	1415.15
25	747.70	5020.73	118.42	13.69	426.74	415.10	4664.14	297.92	291.60	1601.24
30	870.10	5611.90	139.90	16.91	494.05	477.80	5170.85	338.20	343.18	1803.53
35	1007.02	6244.73	164.32	20.71	569.11	-	6335.98	383.80	401.48	2002.43
40	1159.53	6918.44	191.96	25.17	-	-	-	434.72	467.02	2258.25
45	1328.73	7631.46	223.07	30.38		-	-	478.80	540.35	2495.43
50	1515.83	-	257.94	36.40	-	-	-	521.36	622.00	2781.48
55	1721.98	-	266.84	43.32	-	-	-	-	712.50	3069.07
60	1948.21	-	340.05	51.22	-	-	-	-	812.38	3374.02
65	2196.51	-	387.85	-	-	-	-	-	922.14	3696.15
70	2467.55	-	440.50	-	-	-	-	-	-	4035.32
75	2763.00		498.27	-	-	-	-	-	-	-
80	3084.31	-	561.41	-	-	-	-	-	-	-
85	3433.09	-	630.16	-	-	-	-	-	-	-
90	3810.92	-	704.75	-	-	-	-	-	-	-
95	4219.57	-	785.39	-	-		-	-	-	-
100	4660.82	-	872.28	-	-	-	-	-	-	-

VAPOR PRESSURE.

TABLE 140. — Vapor Pressure of Ethyl Alcohol.*

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
	Vapor pressure in millimeters of mercury at 0° C.									
0°	12.24	13.18	14.15	15.16	16.21	17.31	18.46	19.68	20.98	22.34
10	23.78	25.31	27.94	28.67	30.50	32.44	34.49	36.67	38.97	41.40
20	44.00	46.66	49.47	52.44	55.56	58.86	62.33	65.97	69.80	73.83
30	78.06	82.50	87.17	92.07	97.21	102.60	108.24	114.15	120.35	126.86
40	133.70	140.75	148.10	155.80	163.80	172.20	181.00	190.10	199.65	209.60
50	220.00	230.80	242.50	253.80	265.90	278.60	291.85	305.65	319.95	334.85
60	350.30	366.40	383.10	400.40	418.35	437.00	456.35	476.45	497.25	518.85
70	541.20	564.35	588.35	613.20	638.95	665.55	693.10	721.55	751.00	781.45

From the formula $\log p = a + b\alpha^t + c\beta^t$ Ramsay and Young obtain the following numbers.†

Temp. C.	0°	10°	20°	30°	40°	50°	60°	70°	80°	80°
	Vapor pressure in millimeters of mercury at 0° C.									
0°	12.24	23.73	43.97	78.11	133.42	219.82	350.21	540.91	811.81	1186.5
100	1692.3	2359.8	3223.0	4318.7	5686.6	7368.7	9409.9	11858.	14764.	18185.
200	22182.	26825.	32196.	38389.	45519.					

TABLE 141. — Vapor Pressure of Methyl Alcohol.‡

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
	Vapor pressure in millimeters of mercury at 0° C.									
0°	29.97	31.6	33.6	35.6	37.8	40.2	42.6	45.2	47.9	50.8
10	53.8	57.0	60.3	63.8	67.5	71.4	75.5	79.8	84.3	89.0
20	94.0	99.2	104.7	110.4	116.5	122.7	129.3	136.2	143.4	151.0
30	158.9	167.1	175.7	184.7	194.1	203.9	214.1	224.7	235.8	247.4
40	259.4	271.9	285.0	298.5	312.6	327.3	342.5	358.3	374.7	391.7
50	409.4	427.7	446.6	466.3	486.6	507.7	529.5	552.0	575.3	599.4
60	624.3	650.0	676.5	703.8	732.0	761.1	791.1	822.0	–	–

* This table has been compiled from results published by Ramsay and Young (Jour. Chem. Soc. vol. 47, and Phil. Trans. Roy. Soc., 1886).

† In this formula $a = 5.0720301$; $\log b = \bar{2}.6406131$; $\log c = 0.6050854$; $\log \alpha = 0.003377538$; $\log \beta = \bar{1}.99682424$ (c is negative).

‡ Taken from a paper by Dittmar and Fawsitt (Trans. Roy. Soc. Edin. vol. 33).

TABLE 142.

VAPOR PRESSURE.*

Carbon Disulphide, Chlorobenzene, Bromobenzene, and Aniline.

Temp.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
					(a) CARBON DISULPHIDE.					
0°	127.90	133.85	140.05	146.45	153.10	160.00	167.15	174.60	182.25	190.20
10	198.45	207.00	215.80	224.95	234.40	244.15	254.25	264.65	275.40	286.55
20	298.05	309.90	322.10	334.70	347.70	361.10	374.95	389.20	403.90	419.00
30	434.60	450.65	467.15	484.15	501.65	519.65	538.15	557.15	576.75	596.85
40	617.50	638.70	660.50	682.90	705.90	729.50	753.75	778.60	804.10	830.25
					(b) CHLOROBENZENE.					
20°	8.65	9.14	9.66	10.21	10.79	11.40	12.04	12.71	13.42	14.17
30	14.95	15.77	16.63	17.53	18.47	19.45	20.48	21.56	22.69	23.87
40	25.10	26.38	27.72	29.12	30.58	32.10	33.69	35.35	37.08	38.88
50	40.75	42.69	44.72	46.84	49.05	51.35	53.74	56.22	58.79	61.45
60	64.20	67.06	70.03	73.11	76.30	79.60	83.02	86.56	90.22	94.00
70	97.90	101.95	106.10	110.41	114.85	119.45	124.20	129.10	134.15	139.40
80	144.80	150.30	156.05	161.95	168.00	174.25	181.70	187.30	194.10	201.15
90	208.35	215.80	223.45	231.30	239.35	247.70	256.20	265.00	274.00	283.25
100	292.75	302.50	312.50	322.80	333.35	344.15	355.25	366.65	378.30	390.25
110	402.55	415.10	427.95	441.15	454.65	468.50	482.65	497.20	512.05	527.25
120	542.80	558.70	575.05	591.70	608.75	626.15	643.95	662.15	680.75	699.65
130	718.95	738.65	758.80	–	–	–	–	–	–	–
					(c) BROMOBENZENE.					
40°	–	–	–		–	12.40	13.06	13.75	14.47	15.22
50	16.00	16.82	17.68	18.58	19.52	20.50	21.52	22.59	23.71	24.88
60	26.10	27.36	28.68	30.06	31.50	33.00	34.56	36.18	37.86	39.60
70	41.40	43.28	45.24	47.28	49.40	51.60	53.88	56.25	58.71	61.26
80	63.90	66.64	69.48	72.42	75.46	78.60	81.84	85.20	88.68	92.28
90	96.00	99.84	103.80	107.88	112.08	116.40	120.86	125.46	130.20	135.08
100	140.10	145.26	150.57	156.03	161.64	167.40	173.32	179.41	185.67	192.10
110	198.70	205.48	212.44	219.58	226.90	234.40	242.10	250.00	258.10	266.40
120	274.90	283.65	292.60	301.75	311.15	320.80	330.70	340.80	351.15	361.80
130	372.65	383.75	395.10	406.70	418.60	430.75	443.20	455.90	468.90	482.20
140	495.80	509.70	523.90	538.40	553.20	568.35	583.85	599.65	615.75	632.25
150	649.05	666.25	683.80	701.65	719.95	738.55	757.55	776.95	796.70	816.90
					(d) ANILINE.					
80°	18.80	19.78	20.79	21.83	22.90	24.00	25.14	26.32	27.54	28.80
90	30.10	31.44	32.83	34.27	35.76	37.30	38.90	40.56	42.28	44.06
100	45.90	47.80	49.78	51.84	53.98	56.20	58.50	60.88	63.34	65.88
110	68.50	71.22	74.04	76.96	79.98	83.10	86.32	89.66	93.12	96.70
120	100.40	104.22	108.17	112.25	116.46	120.80	125.28	129.91	134.69	139.62
130	144.70	149.94	155.34	160.90	166.62	172.50	178.56	184.80	191.22	197.82
140	204.60	211.58	218.76	226.14	233.72	241.50	249.50	257.72	266.16	274.82
150	283.70	292.80	302.15	311.75	321.60	331.70	342.05	352.65	363.50	374.60
160	386.00	397.65	409.60	421.80	434.30	447.10	460.20	473.60	487.25	501.25
170	515.60	530.20	545.20	560.45	576.10	592.05	608.35	625.05	642.05	659.45
180	677.15	695.30	713.75	732.65	751.90	771.50	–	–	–	–

* These tables of vapor pressures are quoted from results published by Ramsay and Young (Jour. Chem. Soc. vol. 47). The tables are intended to give a series suitable for hot-jacket purposes.

VAPOR PRESSURE.

Methyl Salicylate, Bromonaphthaline, and Mercury.

Temp. C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
					(e) METHYL SALICYLATE.					
70°	2.40	2.58	2.77	2.97	3.18	3.40	3.62	3.85	4.09	4.34
80	4.60	4.87	5.15	5.44	5.74	6.05	6.37	6.70	7.05	7.42
90	7.80	8.20	8.62	9.06	9.52	9.95	10.44	10.95	11.48	12.03
100	12.60	13.20	13.82	14.47	15.15	15.85	16.58	17.34	18.13	18.95
110	19.80	20.68	21.60	22.55	23.53	24.55	25.61	26.71	27.85	29.03
120	30.25	31.52	32.84	34.21	35.63	37.10	38.67	40.24	41.84	43.54
130	45.30	47.12	49.01	50.96	52.97	55.05	57.20	59.43	61.73	64.10
140	66.55	69.08	71.69	74.38	77.15	80.00	82.94	85.97	89.09	92.30
150	95.60	99.00	102.50	106.10	109.80	113.60	117.51	121.53	125.66	129.90
160	134.25	138.72	143.31	148.03	152.88	157.85	162.95	168.19	173.56	179.06
170	184.70	190.48	196.41	202.49	208.72	215.10	221.65	228.30	235.15	242.15
180	249.35	256.70	264.20	271.90	279.75	287.80	296.00	304.48	313.05	321.85
190	330.85	340.05	349.45	359.05	368.85	378.90	389.15	399.60	410.30	421.20
200	432.35	443.75	455.35	467.25	479.35	491.70	504.35	517.25	530.40	543.80
210	557.50	571.45	585.70	600.25	615.05	630.15	645.55	661.25	677.25	693.60
220	710.10	727.05	744.35	761.90	779.85	798.10				
					(f) BROMONAPHTHALINE.					
110°	3.60	3.74	3.89	4.05	4.22	4.40	4.59	4.79	5.00	5.22
120	5.45	5.70	5.96	6.23	6.51	6.80	7.10	7.42	7.76	8.12
130	8.50	8.89	9.29	9.71	10.15	10.60	11.07	11.56	12.07	12.60
140	13.15	13.72	14.31	14.92	15.55	16.20	16.87	17.56	18.28	19.03
150	19.80	20.59	21.41	22.25	23.11	24.00	24.92	25.86	26.83	27.83
160	28.85	29.90	30.98	32.09	33.23	34.40	35.60	36.83	38.10	39.41
170	40.75	42.12	43.53	44.99	46.50	48.05	49.64	51.28	52.96	54.68
180	56.45	58.27	60.14	62.04	64.06	66.10	68.19	70.34	72.55	74.82
190	77.15	79.54	81.99	84.51	87.10	89.75	92.47	95.26	98.12	101.05
200	104.05	107.12	110.27	113.50	116.81	120.20	123.67	127.22	130.86	134.59
210	138.40	142.30	146.29	150.38	154.57	158.85	163.25	167.70	172.30	176.95
220	181.75	186.65	191.65	196.75	202.00	207.35	212.80	218.40	224.15	230.00
230	235.95	242.05	248.30	254.65	261.20	267.85	274.65	281.60	288.70	295.95
240	303.35	310.90	318.65	326.50	334.55	342.75	351.10	359.65	368.40	377.30
250	386.35	395.60	405.05	414.65	424.45	434.45	444.65	455.00	465.60	476.35
260	487.35	498.55	509.90	521.50	533.35	545.35	557.60	570.05	582.70	595.60
270	608.75	622.10	635.70	649.50	663.55	677.85	692.40	707.15	722.15	737.45
					(g) MERCURY.					
270°	123.92	126.97	130.08	133.26	136.50	139.81	143.18	146.61	150.12	153.70
280	157.35	161.07	164.86	168.73	172.67	176.79	180.88	185.05	189.30	193.63
290	198.04	202.53	207.10	211.76	216.50	221.33	226.25	231.25	236.34	241.53
300	246.81	252.18	257.65	263.21	268.87	274.63	280.48	286.43	292.49	298.66
310	304.93	311.30	317.78	324.37	331.08	337.89	344.81	351.85	359.00	366.28
320	373.67	381.18	388.81	396.56	404.43	412.44	420.58	428.83	437.22	445.75
330	454.41	463.20	472.12	481.19	490.40	499.74	509.22	518.85	528.63	538.56
340	548.64	558.87	569.25	579.78	590.48	601.33	612.34	623.51	634.85	646.36
350	658.03	669.86	681.86	694.04	706.40	718.94	731.65	744.54	757.61	770.87
360	784.31									

TABLE 143.

VAPOR PRESSURE OF SOLUTIONS OF SALTS IN WATER.*

The first column gives the chemical formula of the salt. The headings of the other columns give the number of gram-molecules of the salt in a liter of water. The numbers in these columns give the lowering of the vapor pressure produced by the salt at the temperature of boiling water under 76 centimeters barometric pressure.

Substance.	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
$Al_2(SO_4)_3$	12.8	36.5							
$AlCl_3$	22.5	61.0	179.0	318.0					
$Ba(SO_3)_2$	6.6	15.4	34.4						
$Ba(OH)_2$	12.3	22.5	39.0						
$Ba(NO_3)_2$	13.5	27.0							
$Ba(ClO_3)_2$	15.8	33.3	70.5	108.2					
$BaCl_2$	16.4	36.7	77.6						
$BaBr_2$	16.8	38.8	91.4	150.0	204.7				
$Ca(SO_3)_2$	9.9	23.0	56.0	106.0					
$Ca(NO_3)_2$	16.4	34.8	74.6	139.3	161.7	205.4			
$CaCl_2$	17.0	39.8	95.3	166.6	241.5	319.5			
$CaBr_2$	17.7	44.2	105.8	191.0	283.3	368.5			
$CdSO_4$	4.1	8.9	18.1						
CdI_2	7.6	14.8	33.5	52.7					
$CdBr_2$	8.6	17.8	36.7	55.7	80.0				
$CdCl_2$	9.6	18.8	36.7	57.0	77.3	99.0			
$Cd(NO_3)_2$	15.9	36.1	78.0	122.2					
$Cd(ClO_3)_2$	17.5								
$CoSO_4$	5.5	10.7	22.9	45.5					
$CoCl_2$	15.0	34.8	83.0	136.0	186.4				
$Co(NO_3)_2$	17.3	39.2	89.0	152.0	218.7	282.0	332.0		
$FeSO_4$	5.8	10.7	24.0	42.4					
H_3BO_3	6.0	12.3	25.1	38.0	51.0				
H_3PO_4	6.6	14.0	28.6	45.2	62.0	81.5	103.0	146.9	189.5
H_3AsO_4	7.3	15.0	30.2	46.4	64.9				
H_2SO_4	12.9	26.5	62.8	104.0	148.0	198.4	247.0	343.2	
KH_2PO_4	10.2	19.5	33.3	47.8	60.5	73.1	85.2		
KNO_3	10.3	21.1	40.1	57.6	74.5	88.2	102.1	126.3	148.0
$KClO_3$	10.6	21.6	42.8	62.1	80.0				
$KBrO_3$	10.9	22.4	45.0						
$KHSO_4$	10.9	21.9	43.3	65.3	85.5	107.8	129.2	170.0	
KNO_2	11.1	22.8	44.8	67.0	90.0	110.5	130.7	167.0	198.8
$KClO_4$	11.5	22.3							
KCl	12.2	24.4	48.8	74.1	100.9	128.5	152.2		
$KHCO_2$	11.6	23.6	59.0	77.6	104.2	132.0	160.0	210.0	255.0
KI	12.5	25.3	52.2	82.6	112.2	141.5	171.8	225.5	278.5
$K_2C_2O_4$	13.9	28.3	59.8	94.2	131.0				
K_2WO_4	13.9	33.0	75.0	123.8	175.4	226.4			
K_2CO_3	14.4	31.0	68.3	105.5	152.0	209.0	258.5	350.0	
KOH	15.0	29.5	64.0	99.2	140.0	181.8	223.0	309.5	387.8
K_2CrO_4	16.2	29.5	60.0						
$LiNO_3$	12.2	25.9	55.7	88.9	122.2	155.1	188.0	253.4	309.2
$LiCl$	12.1	25.5	57.1	95.0	132.5	175.5	219.5	311.5	393.5
$LiBr$	12.2	26.2	60.0	97.0	140.0	186.3	241.5	341.5	438.0
Li_2SO_4	13.3	28.1	56.8	89.0					
$LiHSO_4$	12.8	27.0	57.0	93.0	130.0	168.0			
LiI	13.6	28.6	64.7	105.2	154.5	206.0	264.0	357.0	445.0
Li_2SiFl_6	15.4	34.0	70.0	106.0					
$LiOH$	15.9	37.4	78.1						
Li_2CrO_4	16.4	32.6	74.0	120.0	171.0				

* Compiled from a table by Tammano, "Mém. Ac. St. Petersb." 35, No. 9, 1887. See also Referate, "Zeit. f. Phys." ch. 2, 42, 1886.

VAPOR PRESSURE OF SOLUTIONS OF SALTS IN WATER.

Substance.	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
$MgSO_4$	6.5	12.0	24.5	47.5					
$MgCl_2$	16.8	39.0	100.5	183.3	277.0	377.0			
$Mg(NO_3)_2$	17.6	42.0	101.0	174.8					
$MgBr_2$	17.9	44.0	115.8	205.3	298.5				
$MgH_2(SO_4)_2$	18.3	46.0	116.0						
$MnSO_4$	6.0	10.5	21.0						
$MnCl_2$	15.0	34.0	76.0	122.3	167.0	209.0			
NaH_2PO_4	10.5	20.0	36.5	51.7	66.8	82.0	96.5	126.7	157.1
$NaHSO_4$	10.9	22.1	47.3	75.0	100.2	126.1	148.5	189.7	231.4
$NaNO_3$	10.6	22.5	46.2	68.1	90.3	111.5	131.7	167.8	198.8
$NaClO_3$	10.5	23.0	48.4	73.5	98.5	123.3	147.5	196.5	223.5
$(NaPO_3)_6$	11.6								
$NaOH$	11.8	22.8	48.2	77.3	107.5	139.1	172.5	243.3	314.0
$NaNO_2$	11.6	24.4	50.0	75.0	98.2	122.5	146.5	189.0	226.2
$NaHPO_4$	12.1	23.5	43.0	60.0	78.7	99.8	122.1		
$NaHCO_2$	12.9	24.1	48.2	77.6	102.2	127.8	152.0	198.0	239.4
$NaSO_4$	12.6	25.0	48.9	74.2					
$NaCl$	12.3	25.2	52.1	80.0	111.0	143.0	176.5		
$NaBrO_3$	12.1	25.0	54.1	81.3	108.8	136.0			
$NaBr$	12.6	25.9	57.0	89.2	124.2	159.5	197.5	268.0	
NaI	12.1	25.6	60.2	99.5	136.7	177.5	221.0	301.5	370.0
$Na_4P_2O_7$	13.2	22.0							
Na_2CO_3	14.3	27.3	53.5	80.2	111.0				
$Na_2C_2O_4$	14.5	30.0	65.8	105.8	146.0				
Na_2WO_4	14.8	33.6	71.6	115.7	162.6				
Na_3PO_4	16.5	30.0	52.5						
$(NaPO_3)_3$	17.1	36.5							
NH_4NO_3	12.8	22.0	42.1	62.7	82.9	103.8	121.0	152.2	180.0
$(NH_4)_2SiFl_6$	11.5	25.0	44.5						
NH_4Cl	12.0	23.7	45.1	69.3	94.2	118.5	138.2	179.0	213.8
NH_4HSO_4	11.5	22.0	46.8	71.0	94.5	118.	139.0	181.2	218.0
$(NH_4)_2SO_4$	11.0	24.0	46.5	69.5	93.0	117.0	141.8		
NH_4Br	11.9	23.9	48.8	74.1	99.4	121.5	145.5	190.2	228.5
NH_4I	12.9	25.1	49.8	78.5	104.5	132.3	156.0	200.0	243.5
$NiSO_4$	5.0	10.2	21.5						
$NiCl_2$	16.1	37.0	86.7	147.0	212.8				
$Ni(NO_3)_2$	16.1	37.3	91.3	156.2	235.0				
$Pb(NO_3)_2$	12.3	23.5	45.0	63.0					
$Sr(SO_3)_2$	7.2	20.3	47.0						
$Sr(NO_3)_2$	15.8	31.0	64.0	97.4	131.4				
$SrCl_2$	16.8	38.8	91.4	156.8	223.3	281.5			
$SrBr_2$	17.8	42.0	101.1	179.0	267.0				
$ZnSO_4$	4.9	10.4	21.5	42.1	66.2				
$ZnCl_2$	9.2	18.7	46.2	75.0	107.0	153.0	195.0		
$Zn(NO_3)_2$	16.6	39.0	93.5	157.5	223.8				

PRESSURE OF SATURATED AQUEOUS VAPOR.

TABLE 144. — At Low Temperature. Over Ice.

Temperatures Centigrade.

	0	1	2	3	4	5	6	7	8	9
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
—60	0.008	0.007	0.005	0.004	0.003	0.003				
—50	.029	.026	.023	.021	.018	.016	0.014	0.012	0.010	0.009
—40	.094	.083	.074	.066	.059	.052	.047	.042	.037	.033
—30	.280	.252	.226	.203	.182	.163	.146	.131	.117	.105
—20	0.770	0.699	0.633	0.574	0.519	0.469	0.424	0.383	.345	.311
—10	1.947	1.780	1.627	1.486	1.356	1.237	1.127	1.026	0.933	0.848
— 0	4.579	4.215	3.879	3.566	3.277	3.009	2.762	2.533	2.322	2.127

Taken from Landolt-Börnstein, Physikalisch-Chemische Tabellen, 1912.

TABLE 145. — At Low Temperature. Over Water.

	0	1	2	3	4	5	6	7	8	9
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
—10	2.144	1.979	1.826	1.684	1.551	1.429	1.315			
— 0	4.579	4.255	3.952	3.669	3.404	3.158	2.928	2.712	2.509	2.321
+ 0	4.579	4.926	5.294	5.685	6.101	6.543	7.014	7.514	8.046	8.610

Taken from Landolt-Börnstein, Physikalisch-Chemische Tabellen, 1912.

TABLE 146. — 0° to 50° C. Hydrogen Scale.

Values interpolated between those given by Scheel and Heuse for every degree between 0° and 50° C. Annalen der Physik. (4), 31, p. 731, 1910.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
0°	4.579	4.613	4.647	4.681	4.715	4.750	4.785	4.820	4.855	4.890
1.	4.926	4.962	4.998	5.034	5.071	5.107	5.144	5.181	5.218	5.256
2.	5.294	5.332	5.370	5.408	5.447	5.486	5.525	5.564	5.604	5.644
3.	5.685	5.725	5.766	5.807	5.848	5.889	5.931	5.973	6.015	6.058
4.	6.101	6.144	6.187	6.230	6.274	6.318	6.363	6.408	6.453	6.498
5.	6.543	6.589	6.635	6.681	6.728	6.775	6.822	6.870	6.918	6.966
6.	7.014	7.063	7.112	7.171	7.210	7.260	7.310	7.361	6.412	7.463
7.	7.514	7.566	7.618	7.670	7.723	7.776	7.829	7.883	7.937	7.991
8.	8.046	8.101	8.156	8.212	8.268	8.324	8.381	8.438	8.495	8.552
9.	8.609	8.668	8.727	8.786	8.845	8.905	8.965	9.026	9.087	9.148
10.	9.210	9.272	9.334	9.396	9.459	9.522	9.586	9.650	9.715	9.780
11.	9.845	9.911	9.977	10.043	10.110	10.177	10.245	10.313	10.381	10.450
12.	10.519	10.589	10.659	10.729	10.800	10.871	10.943	11.015	11.087	11.160
13.	11.233	11.307	11.381	11.455	11.530	11.605	11.681	11.757	11.834	11.912
14.	11.989	12.067	12.146	12.225	12.304	12.384	12.464	12.545	12.626	12.708
15.	12.790	12.873	12.956	13.039	13.123	13.207	13.292	13.378	13.464	13.550
16.	13.637	13.724	13.812	13.900	13.989	14.078	14.168	14.258	14.350	14.441
17.	14.533	14.625	14.718	14.811	14.905	14.999	15.094	15.190	15.286	15.383
18.	15.480	15.578	15.676	15.775	15.874	15.974	16.074	16.175	16.276	16.378
19.	16.481	16.584	16.688	16.792	16.897	17.003	17.109	17.216	17.323	17.430
20.	17.539	17.648	17.757	17.867	17.977	18.088	18.200	18.313	18.426	18.540
21.	18.655	18.770	18.886	19.002	19.119	19.236	19.354	19.473	19.592	19.712
22.	19.832	19.953	20.075	20.197	20.320	20.444	20.569	20.694	20.820	20.947
23.	21.074	21.202	21.330	21.459	21.589	21.720	21.851	21.983	22.116	22.249
24.	22.383	22.518	22.654	22.790	22.927	23.065	23.203	23.342	23.482	23.622
25.	23.763	23.905	24.048	24.192	24.336	24.481	24.627	24.773	24.920	25.068

PRESSURE OF SATURATED AQUEOUS VAPOR.

TABLE 146 (*continued*). — 0° to 50° C. Hydrogen Scale.

	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
26°	25.217	25.367	25.517	25.668	25.820	25.972	26.125	26.279	26.434	26.590
27.	26.747	26.904	27.062	27.221	27.381	27.542	27.704	27.866	28.029	28.193
28.	28.358	28.524	28.690	28.857	29.025	29.194	29.364	29.535	29.707	29.879
29.	30.052	30.226	30.401	30.577	30.754	30.932	31.111	31.291	31.471	31.653
30.	31.834	32.017	32.201	32.386	32.572	32.759	32.947	33.135	33.324	33.514
31.	33.706	33.899	34.093	34.288	34.483	34.679	34.876	35.074	35.273	35.473
32.	35.674	35.876	36.079	36.283	36.488	36.694	36.901	37.109	37.318	37.529
33.	37.741	37.953	38.166	38.380	38.595	38.812	39.030	39.249	39.469	39.689
34.	39.911	40.134	40.358	40.583	40.809	41.036	41.264	41.493	41.723	41.955
35.	42.188	42.422	42.657	42.893	43.130	43.368	43.607	43.847	44.089	44.332
36.	44.577	44.82	45.06	45.30	45.55	45.80	46.05	46.30	46.56	46.82
37.	47.082	47.34	47.60	47.86	48.12	48.38	48.64	48.90	49.17	49.44
38.	49.708	49.98	50.25	50.52	50.79	51.06	51.33	51.60	51.88	52.16
39.	52.459	52.74	53.02	53.30	53.58	53.87	54.16	54.45	54.75	55.05
40.	55.341	55.63	55.93	56.23	56.53	56.83	57.13	57.43	57.74	58.05
41.	58.36	58.67	58.98	59.29	59.60	59.92	60.24	60.56	60.88	61.20
42.	61.52	61.84	62.16	62.49	62.82	63.15	63.48	63.81	64.14	64.48
43.	64.82	65.16	65.50	65.84	66.18	66.53	66.88	67.23	67.58	67.93
44.	68.28	68.63	68.99	69.35	69.71	70.07	70.43	70.79	71.16	71.53
45.	71.90	72.27	72.64	73.01	73.38	73.76	74.14	74.52	74.90	75.28
46.	75.67	76.06	76.45	76.84	77.23	77.62	78.02	78.42	78.82	79.22
47.	79.62	80.03	80.43	80.84	81.25	81.66	82.07	82.48	82.90	83.32
48.	83.74	84.16	84.59	85.02	85.45	85.88	86.31	86.74	87.17	87.61
49.	88.05	88.49	88.93	89.37	89.82	90.27	90.72	91.17	91.62	92.08

TABLE 147. 50° to 374° C. Hydrogen Scale.

	0	1	2	3	4	5	6	7	8	9
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
50°	92.54	97.24	102.13	107.24	112.56	118.11	123.89	129.90	136.16	142.68
60.	149.46	156.52	163.85	171.47	179.40	187.64	196.19	205.07	214.29	223.86
70.	233.79	244.11	254.82	265.91	277.41	289.32	301.65	314.42	327.64	341.32
80.	355.47	370.11	385.25	400.90	417.08	433.79	451.07	468.91	487.33	506.36
90.	526.00	546.27	567.19	588.77	611.04	634.01	657.69	682.11	707.29	733.24
100.	760.00	787.57	815.9	845.1	875.1	906.1	937.9	970.6	1004.3	1038.8
110.	1074.5	1111.1	1148.7	1187.4	1227.1	1267.9	1309.8	1352.8	1397.0	1442.4
120.	1488.9	1536.6	1585.7	1636.0	1687.5	1740.5	1794.7	1850.3	1907.3	1965.8
130.	2025.6	2086.9	2149.8	2214.0	2280.0	2347.5	2416.5	2487.3	2559.7	2633.8
140.	2709.5	2787.1	2866.4	2947.7	3030.5	3115.3	3202.1	3290.8	3381.3	3474.0
150.	3568.7	3665.3	3764.1	3864.9	3968.	4073.	4181.	4290.	4402.	4517.
160.	4[illegible]33	4752	4874	4998	5124	5253	5384	5518	5655	5794
170.	5937	6081	6229	6379	6533	6689	6848	7010	7175	7343
180.	7514	7688	7866	8046	8230	8417	8608	8802	8999	9200
190.	9404	9612	9823	10038	10256	10479	10705	10934	11168	11406
200.	11647	11893	12143	12397	12654	12916	13183	13453	13728	14007
210.	14291	14578	14871	15167	15469	15774	16085	16401	16721	17046
220.	17376	17710	18049	18394	18743	19098	19458	19823	20193	20570
230.	20950	21336	21728	22125	22528	22936	23350	23770	24195	24626
240.	25064	25506	25956	26412	26873	27341	27815	28294	28780	29272
250.	29771	30276	30788	31308	31833	32364	32903	33448	34001	34561
260.	35127	35700	36280	36868	37463	38065	38675	39291	39915	40547
270.	41186	41832	42487	43150	43820	44498	45184	45879	46580	47290
280.	48011	48738	49474	50219	50972	51734	52506	53288	54079	54878
290.	55680	56500	57330	58170	59010	59860	60730	61610	62490	63390
300.	64290	65200	66120	67060	68000	68950	69910	70890	71870	72860
310.	73860	74880	75900	76940	77980	79040	80110	81180	82270	83370
320.	84480	85610	86750	87900	89050	90220	91400	92600	93820	95040
330.	96270	97510	98770	100040	101320	102610	103930	105250	106580	107930
340.	109300	110670	112050	113450	114870	116300	117750	119210	120680	122160
350.	123660	125170	126690	128230	129790	131370	132960	134560	136180	137820
360.	139480	141150	142850	144560	146300	148100	149900	151700	153500	155300
370.	157200	159100	161000	163000	164900					

Taken from Landolt-Börnstein Tables and based upon the following data: 50-70°, Nernst, Verh. d. D. Phys. Ges. 12, p. 565, 1910; 70-100°, Regnault, computed by Broch, 1881, improved by Wiebe, ZS. fur Instrum. 13, p. 329, 1893, also Tafeln für die Spannkraft des Wasserdampfes, Braunschweig, 1903; 100-374°, Holborn, Henning, Baumann, Annalen der Physik, 26, p. 833, 1908, 31, p. 945, 1910.

TABLE 148. — Weight in Grains of the Aqueous Vapor contained in a Cubic Foot of Saturated Air.*

Temp. °F.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
−10	0.285	0.270	0.257	0.243	0.231	0.218	0.207	0.196	0.184	0.174
−0	0.481	0.457	0.434	0.411	0.389	0.370	0.350	0.332	0.316	0.300
+0	0.481	0.505	0.529	0.554	0.582	0.610	0.639	0.671	0.704	0.739
10	0.776	0.816	0.856	0.898	0.941	0.985	1.032	1.079	1.128	1.181
20	1.235	1.294	1.355	1.418	1.483	1.551	1.623	1.697	1.773	1.853
30	1.935	2.022	2.113	2.194	2.279	2.366	2.457	2.550	2.646	2.746
40	2.849	2.955	3.064	3.177	3.294	3.414	3.539	3.667	3.800	3.936
50	4.076	4.222	4.372	4.526	4.685	4.849	5.018	5.191	5.370	5.555
60	5.745	5.941	6.142	6.349	6.563	6.782	7.009	7.241	7.480	7.726
70	7.980	8.240	8.508	8.782	9.066	9.356	9.655	9.962	10.277	10.601
80	10.934	11.275	11.626	11.987	12.356	12.736	13.127	13.526	13.937	14.359
90	14.790	15.234	15.689	16.155	16.634	17.124	17.626	18.142	18.671	19.212
100	19.766	20.335	20.917	21.514	22.125	22.750	23.392	24.048	24.720	25.408
110	26.112	26.832	27.570	28.325	29.096	29.887	-	-	-	-

* See "Smithsonian Meteorological Tables," pp 132–133.

TABLE 149. — Weight in Grams of the Aqueous Vapor contained in a Cubic Meter of Saturated Air.

Temp. °C.	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
−20	0.892	0.810	0.737	0.673	0.613	0.557	0.505	0.457	0.413	0.373
−10	2.154	1.978	1.811	1.658	1.519	1.395	1.282	1.177	1.079	0.982
−0	4.835	4.468	4.130	3.813	3.518	3.244	2.988	2.752	2.537	2.340
+0	4.835	5.176	5.538	5.922	6.330	6.761	7.219	7.703	8.215	8.757
10	9.330	9.935	10.574	11.249	11.961	12.712	13.505	14.339	15.218	16.144
20	17.118	18.143	19.222	20.355	21.546	22.796	24.109	25.487	26.933	28.450
30	30.039	31.704	33.449	35.275	37.187	39.187	41.279	43.465	45.751	48.138

Table 150.

PRESSURE OF AQUEOUS VAPOR IN THE ATMOSPHERE.

This table gives the vapor pressure corresponding to various values of the difference $t - t_1$ between the readings of dry and wet bulb thermometers and the temperature t_1 of the wet bulb thermometer. The differences $t - t_1$ are given by two-degree steps in the top line, and t_1 by degrees in the first column. Temperatures in Centigrade degrees and Regnault's vapor pressures in millimeters of mercury are used throughout the table. The table was calculated for barometric pressure B equal to 76 centimeters, and a correction is given for each centimeter at the top of the columns.* Ventilating velocity of wet thermometer about 3 meters per second.

t_1	$t-t_1 = 0$	2	4	6	8	10	12	14	18	18	20	Difference per 1° of $t-t_1$
Corrections for B per centimeter.†		.013	.026	.040	.053	.066	.079	.092	.106	.119	.132	
−10	1.96	0.96										0.100
−9	2.14	1.14	0.14									0.100
−8	2.33	1.33	0.33									0.100
−7	2.53	1.53	0.53									0.100
−6	2.76	1.76	0.76									0.100
−5	3.01	2.01	1.00									0.100
−4	3.28	2.28	1.27	0.27								0.100
−3	3.57	2.57	1.56	0.56								0.100
−2	3.88	2.88	1.87	0.87								0.100
−1	4.22	3.22	2.21	1.21	0.21							0.100
0	4.60	3.60	2.59	1.59	0.59							0.100
1	4.94	3.93	2.92	1.92	0.92							0.100
2	5.30	4.29	3.29	2.28	1.28	0.27						0.100
3	5.69	4.68	3.68	2.67	1.66	0.66						0.101
4	6.10	5.09	4.09	3.08	2.07	1.06	0.05					0.101
5	6.53	5.52	4.51	3.50	2.49	1.48	0.48					0.101
6	7.00	5.99	4.98	3.97	2.96	1.95	0.94					0.101
7	7.49	6.48	5.47	4.45	3.44	2.43	1.42	0.41				0.101
8	8.02	7.01	5.99	4.98	3.97	2.96	1.94	0.93				0.101
9	8.57	7.56	6.54	5.53	4.51	3.50	2.49	1.48	0.46			0.101
10	9.17	8.16	7.14	6.12	5.11	4.09	3.08	2.07	1.06	0.05		0.101
11	9.79	8.77	7.76	6.74	5.73	4.71	3.69	2.68	1.66	0.64		0.102
12	10.46	9.44	8.43	7.41	6.39	5.37	4.36	3.34	2.32	1.30	0.28	0.102
13	11.16	10.14	9.12	8.10	7.09	6.07	5.05	4.03	3.01	1.99	0.97	0.102
14	11.91	10.89	9.87	8.85	7.83	6.81	5.79	4.77	3.71	2.69	1.67	0.102
15	12.70	11.68	10.66	9.64	8.62	7.60	6.58	5.56	4.54	3.52	2.50	0.102
16	13.54	12.52	11.50	10.47	9.45	8.43	7.41	6.39	5.37	4.35	3.33	0.102
17	14.42	13.40	12.37	11.35	10.33	9.31	8.28	7.26	6.24	5.22	4.20	0.102
18	15.36	14.34	13.31	12.29	11.26	10.24	9.21	8.19	7.17	6.15	5.13	0.102
19	16.35	15.33	14.30	13.27	12.25	11.22	10.20	9.17	8.15	7.13	6.11	0.102
20	17.39	16.37	15.34	14.31	13.28	12.26	11.23	10.21	9.18	8.15	7.12	0.103
21	18.50	17.47	16.45	15.42	14.39	13.36	12.33	11.31	10.28	9.25	8.22	0.103
22	19.66	18.63	17.60	16.57	15.54	14.51	13.48	12.46	11.43	10.40	9.37	0.103
23	20.89	19.86	18.83	17.80	16.77	15.74	14.71	13.68	12.66	11.63	10.60	0.103
24	22.18	21.15	20.12	19.09	18.05	17.02	15.99	14.96	13.94	12.91	11.88	0.103
25	23.55	22.52	21.49	20.45	19.43	18.39	17.36	16.33	15.30	14.27	13.24	0.103
26	24.99	23.96	22.92	21.89	20.86	19.82	18.79	17.76	16.73	15.70	14.67	0.103
27	26.51	25.48	24.44	23.40	22.37	21.34	20.30	19.27	18.24	17.21	16.18	0.103
28	28.10	27.07	26.03	24.99	23.96	22.92	21.89	20.85	19.82	18.79	17.76	0.103
29	29.78	28.75	27.71	26.67	25.63	24.59	23.56	22.52	21.49	20.46	19.43	0.103
30	31.55	30.51	29.47	28.43	27.40	26.36	25.32	24.29	23.25	22.22	21.18	0.104
31	33.41	32.37	31.33	30.29	29.25	28.22	27.18	26.14	25.10	24.07	23.03	0.104
32	35.36	34.32	33.28	32.24	31.21	30.17	29.13	28.09	27.05	26.01	24.97	0.104
33	37.41	36.37	35.33	34.29	33.25	32.22	31.18	30.14	29.10	28.06	27.02	0.104
34	39.57	38.53	37.48	36.44	35.40	34.36	33.32	32.28	31.24	30.20	29.16	0.104
35	41.83	40.79	39.74	38.70	37.66	36.62	35.58	34.54	33.50	32.46	31.42	0.104
36	44.20	43.16	42.11	41.07	40.03	38.99	37.95	36.90	35.86	34.82	33.78	0.104
37	46.69	45.65	44.60	43.56	42.52	41.48	40.44	39.39	38.35	37.31	36.27	0.104
38	49.30	48.26	47.21	46.17	45.13	44.08	43.04	41.99	40.95	39.91	38.87	0.104
39	52.04	51.00	49.95	48.91	47.86	46.82	45.77	44.73	43.68	42.64	41.59	0.105

Example.

$t - t_1 = 7.2$
$t_1 = 10.0$
$B = 74.5$

Tabular number $= 6.12 - 6 \times .101 =$ 5.51
Correction for $B = 1.5 \times .048 \ldots =$ .07
Hence we get $p \ldots =$ 5.58

* The table was calculated from the formula $p = p_1 - 0.00066\, B(t - t_1)(1 + 0.00115\, t_1)$ (Ferrel, Annual Report U. S. Chief Signal Officer, 1886, App. 24).
† When B is less than 76 the correction is to be added, and when B is greater than 76 it is to be subtracted.

DEW-

The first column of this table gives the temperatures of the wet-bulb thermometer, and the top line the difference
the table. The dew-points were computed for a barometric pressure of 76 centimeters. When the barometer differs
and the resulting number added to or subtracted from the tabular number according as the barometer is below or

t_1	$t-t_1=1$	2	3	4	5	6	7	8
	Dew-points corresponding to the difference of temperature given in the above line and the wet-bulb thermometer reading given in first column.							
$\delta T/\delta B=$	.04	.11	.22	.49				
−10	−13.2	−17.9						
−9	12.0	16.0	−22.0					
−8	10.7	14.3	19.4					
−7	9.5	12.7	17.1	−24.0				
−6	8.3	11.2	14.9	20.3				
$\delta T/\delta B=$	.03	.06	.11	.18	.31	.43		
−5	−7.1	−9.7	−12.9	−17.5	−24.5			
−4	6.0	8.3	11.1	14.8	20.1			
−3	4.8	6.9	9.4	12.6	16.8	−23.4		
−2	3.6	5.5	7.8	10.5	13.9	18.9		
−1	2.5	4.2	6.2	8.5	11.5	15.4	−21.0	
$\delta T/\delta B=$	.02	.04	.07	.10	.14	.19	.26	.38
0	−1.3	−2.9	−4.8	−6.8	−9.3	−12.3	−16.5	−22.9
1	0.3	1.7	3.5	5.3	7.6	10.2	13.5	18.3
2	+0.6	0.7	2.2	3.9	6.1	8.3	11.1	14.7
3	1.7	+0.2	1.0	2.6	4.6	6.4	8.9	11.9
4	2.8	1.4	0.0	1.3	3.1	4.7	6.9	9.4
$\delta T/\delta B=$	.02	.03	.05	.07	.09	.11	.14	.18
5	3.8	2.6	+1.2	−0.1	−1.6	−3.2	−5.0	−7.1
6	4.9	3.7	2.5	+1.1	0.2	1.7	3.3	5.2
7	6.0	4.9	3.7	2.4	+1.1	0.3	1.8	3.4
8	7.0	6.0	4.9	3.7	2.5	+1.1	0.3	1.8
9	8.1	7.1	6.1	5.0	3.9	2.6	+1.2	0.1
$\delta T/\delta B=$	.01	.02	.03	.05	.06	.08	.10	.12
10	9.1	8.3	7.3	6.3	5.2	4.1	2.8	+1.5
11	10.2	9.3	8.4	7.5	6.5	5.5	4.3	3.1
12	11.2	10.4	9.6	8.7	7.8	6.8	5.8	4.7
13	12.3	11.5	10.7	9.9	9.1	8.2	7.2	6.2
14	13.3	12.6	11.9	11.1	10.3	9.0	8.6	7.6
$\delta T/\delta B=$	.01	.02	.03	.04	.05	.06	.07	.08
15	14.4	13.7	13.0	12.3	11.5	10.8	9.9	9.1
16	15.4	14.8	14.1	13.5	12.7	12.0	11.3	10.5
17	16.4	15.8	15.2	14.6	13.9	13.3	12.6	11.8
18	17.5	16.9	16.3	15.7	15.1	14.5	13.8	13.1
19	18.5	18.0	17.4	16.9	16.3	15.7	15.1	14.4
$\delta T/\delta B=$	.005	.01	.015	.02	.027	.033	.04	.05
20	19.5	19.0	18.5	18.0	17.4	16.9	16.3	15.7
21	20.5	20.1	19.6	19.1	18.6	18.1	17.5	17.0
22	21.6	21.1	20.7	20.2	19.7	19.2	18.7	18.2
23	22.6	22.2	21.7	21.3	20.8	20.4	19.9	19.4
24	23.6	23.2	22.8	22.4	22.0	21.5	21.1	20.6
$\delta T/\delta B=$	.005	.01	.015	.02	.025	.03	.035	.04
25	24.6	24.2	23.9	23.5	23.1	22.7	22.2	21.8
26	25.6	25.3	24.9	24.5	24.2	23.8	23.4	23.0
27	26.7	26.3	26.0	25.6	25.3	24.9	24.5	24.1
28	27.7	27.3	27.0	26.7	26.4	26.0	25.7	25.3
29	28.7	28.4	28.1	27.8	27.4	27.1	26.8	26.4
$\delta T/\delta B=$	.003	.006	.01	.013	.017	.019	.022	.026
30	29.7	29.4	29.1	28.8	28.5	28.2	27.9	27.6
31	30.7	30.5	30.2	29.9	29.6	29.3	29.0	28.7
32	31.7	31.5	31.2	30.9	30.7	30.4	30.1	29.8
33	32.8	32.5	32.2	32.0	31.7	31.5	31.2	30.9
34	33.8	33.5	33.3	33.0	32.8	32.5	32.3	32.0
$\delta T/\delta B=$	.003	.005	.008	.010	.013	.016	.019	.021
35	34.8	34.5	34.3	34.1	33.8	33.6	33.4	33.1
36	35.8	35.5	35.3	35.1	34.9	34.6	34.4	34.2
37	36.8	36 6	36.4	36.2	36.0	35.7	35.5	35.3
38	37.8	37.6	37.4	37.2	37.0	36.8	36.6	36.4
39	38.8	38.6	38.4	38.2	38.0	37.9	37.6	37.5

between the dry and the wet bulb, when the dew-point has the values given at corresponding points in the body of from 76 centimeters the corresponding numbers in the lines marked $\delta T/\delta B$ are to be multiplied by the difference, above 76. See examples. Thermometer ventilated at about 3 meters per sec.

t_1	$t-t_1=9$	10	11	12	13	14	15
	Dew-points corresponding to the difference of temperature given in the above line aod the wet-bulb thermometer reading given in first columo.						
$\delta T/\delta B=$	.45	.67					
0							
1							
2	−20.0						
3	15.8	−22.2					
4	12.4	16.8					
$\delta T/\delta B=$	.23	.29	.37	.44	.54	.66	.72
5	−19.8	−13.1	−17.7				
6	7.4	10.1	13.4	−18.1			
7	5.3	7.6	10.1	13.5	−18.3		
8	3.3	5.2	7.4	10.1	13.5	−18.3	
9	1.6	3.2	5.1	7.2	9.9	13.1	−17.2
$\delta T/\delta B=$	.14	.17	.20	.22	.25	.29	.36
10	0.0	−1.3	−3.0	−4.7	−6.8	−9.4	−12.5
11	+1.8	+0.3	1.0	2.6	4.3	6.3	8.8
12	3.5	2.2	+0.8	0.6	2.1	3.7	5.7
13	5.1	3.9	2.7	+1.3	0.1	1.6	3.1
14	6.7	5.6	4.5	3.3	+1.9	+0.5	0.9
$\delta T/\delta B=$	.09	.11	.12	.14	.16	.18	.20
15	8.2	7.2	6.2	5.1	3.9	2.7	+1.3
16	9.6	8.7	7.8	6.8	5.8	4.7	3.5
17	11.0	10.2	9.4	8.5	7.5	6.5	5.5
18	12.4	11.7	10.9	10.1	9.2	8.3	7.4
19	13.8	13.1	12.4	11.6	10.8	10.0	9.1
$\delta T/\delta B=$	.06	.07	.08	.09	.10	.11	.13
20	15.1	14.5	13.8	13.1	12.4	11.6	10.8
21	16.4	15.8	15.2	14.5	13.9	13.2	12.5
22	17.6	17.1	16.5	15.9	15.3	14.7	14.0
23	18.9	18.4	17.9	17.3	16.8	16.2	15.7
24	20.1	19.6	19.2	18.7	18.1	17.6	17.0
$\delta T/\delta B=$	.045	.05	.06	.06	.07	.08	.09
25	21.4	20.9	20.4	20.0	19.5	19.0	18.5
26	22.6	22.1	21.7	21.3	20.8	20.3	19.9
27	23.7	23.4	22.9	22.5	22.1	21.7	21.2
28	24.9	24.5	24.2	23.8	23.4	23.0	22.6
29	26.1	25.7	25.4	25.0	24.6	24.2	23.9
$\delta T/\delta B=$	.031	.035	.041	.047	.053	.06	.07
30	27.2	26.9	26.6	26.2	25.9	25.5	25.2
31	28.4	28.1	27.8	27.4	27.1	26.8	26.4
32	29.5	29.2	28.9	28.6	28.3	28.0	27.7
33	30.7	30.4	30.1	29.8	29.5	29.2	28.9
34	31.8	31.5	31.2	30.9	30.7	30.4	30.1
$\delta T/\delta B=$	.024	.027	.029	.032	.037	.037	.04
35	32.9	32.6	32.4	32.1	31.8	31.6	31.4
36	34.0	33.7	33.5	33.3	33.0	32.8	32.5
37	35.1	34.9	34.6	34.4	34.2	33.9	33.7
38	36.2	35.9	35.7	35.5	35.3	35.1	34.8
39	37.3	37.1	36.8	36.6	36.4	36.2	36.0

EXAMPLES.

(1) Given $B=72$, $t_1=10$, $t-t_1=5$.
Then tabular oumber for $t_1=10$ and $t-t_1=5$ is 5.2
Also $76-72=4$ and $\delta T/\delta B=.06$.
∴ Correction $=0.06\times 4=$ 24
Hence the dew-point is 5.44

(2) Given $B=71.5$, $t_1=7$, $t-t_1=8$.
Then, as above, tabulated number $=$ . . 3.4
$\delta T/\delta B=\frac{.18+.12}{2}=.15$
Correction $=0.15\times 4.5=$ 67
Dew-point $=$ 4.07

RELATIVE HUMIDITY.*

This table gives the humidity of the air, for temperature t and dew-point d in Centigrade degrees, expressed in percentages of the saturation value for the temperature t.

Depression of the dew-point. $t-d$	Dew-point (d). −10	0	+10	+20	+30	Depression of the dew-point. $t-d$	Dew-point (d). −10	0	+10	+20	+30
C.						C.					
0°.0	100	100	100	100	100	**8°.0**	54	57	60	62	64
0.2	98	99	99	99	99	8.2	54	56	59	61	63
0.4	97	97	97	98	98	8.4	53	56	58	60	63
0.6	95	96	96	96	97	8.6	52	55	57	60	62
0.8	94	94	95	95	96	8.8	51	54	57	59	61
1.0	92	93	94	94	94	**9.0**	51	53	56	58	61
1.2	91	92	92	93	93	9.2	50	53	55	58	60
1.4	90	90	91	92	92	9.4	49	52	55	57	59
1.6	88	89	90	91	91	9.6	48	51	54	56	59
1.8	87	88	89	90	90	9.8	48	51	53	56	58
2.0	86	87	88	88	89	**10.0**	47	50	53	55	57
2.2	84	85	86	87	88	10.5	45	48	51	54	
2.4	83	84	85	86	87	11.0	44	47	49	52	
2.6	82	83	84	85	86	11.5	42	45	48	51	
2.8	80	82	83	84	85	12.0	41	44	47	49	
3.0	79	81	82	83	84	**12.0**	39	42	45	48	
3.2	78	80	81	82	83	13.0	38	41	44	46	
3.4	77	79	80	81	82	13.5	37	40	43	45	
3.6	76	77	79	80	82	14.0	35	38	41	44	
3.8	75	76	78	79	81	14.5	34	37	40	43	
4.0	73	75	77	78	80	**15.0**	33	36	39	42	
4.2	72	74	76	77	79	15.5	32	35	38	40	
4.4	71	73	75	77	78	16.0	31	34	37	39	
4.6	70	72	74	76	77	16.5	30	33	36	38	
4.8	69	71	73	75	76	17.0	29	32	35	37	
5.0	68	70	72	74	75	**17.5**	28	31	34	36	
5.2	67	69	71	73	75	18.0	27	30	33	35	
5.4	66	68	70	72	74	18.5	26	29	32	34	
5.6	65	67	69	71	73	19.0	25	28	31	33	
5.8	64	66	69	70	72	19.5	24	27	30	33	
6.0	63	66	68	70	71	**20.0**	24	26	29	32	
6.2	62	65	67	69	71	21.0	22	25	27		
6.4	61	64	66	68	70	22.0	21	23	26		
6.6	60	63	65	67	69	23.0	19	22	24		
6.8	60	62	64	66	68	24.0	18	21	23		
7.0	59	61	63	66	68	**25.0**	17	19	22		
7.2	58	60	63	65	67	26.0	16	18	21		
7.4	57	60	62	64	66	27.0	15	17	20		
7.6	56	59	61	63	65	28.0	14	16	19		
7.8	55	58	60	63	65	29.0	13	15	18		
8.0	54	57	60	62	64	**30.0**	12	14	17		

* Abridged from Table 45 of "Smithsonian Meteorological Tables."

TABLE 153.

VALUES OF 0.378*e*.*

This table gives the humidity term 0.378*e*, which occurs in the equation $\delta = \delta_0 \frac{h}{760} = \delta_0 \frac{B - 0.378e}{760}$ for the calculation of the density of air containing aqueous vapor at pressure *e*; δ_0 is the density of dry air at normal temperature and barometric pressure, *B* the observed barometric pressure, and $h = B - 0.378e$, the pressure corrected for humidity. For values of $\frac{h}{760}$ see Table 154. Temperatures are in degrees Centigrade, and pressures in millimeters of mercury.

Dew Point. °C.	*e* Vapor Pressure (ice).	0.378*e*.	Dew Point. °C.	*e* Vapor Pressure (water).	0.378*e*.	Dew Point. °C.	*e* Vapor Pressure (water).	0.378*e*.
−50	0.034	0.01	0	4.579	1.73	+30	31.555	11.93
45	.061	.02	+1	4.921	1.86	31	33.416	12.63
40	.105	.04	2	5.286	2.00	32	35.372	13.37
35	.173	.07	3	5.675	2.15	33	37.427	14.15
30	.292	.11	4	6.088	2.30	34	39.586	14.96
−25	0.484	0.18	5	6.528	2.47	35	41.853	15.82
24	.534	.20	6	6.997	2.65	36	44.23	16.72
23	.589	.22	7	7.494	2.83	37	46.73	17.66
22	.648	.24	8	8.023	3.03	38	49.35	18.65
21	.714	.27	9	8.584	3.24	39	52.09	19.69
−20	0.787	0.30	10	9.179	3.47	40	54.97	20.78
19	.868	.33	11	9.810	3.71	41	57.98	21.92
18	.955	.36	12	10.479	3.96	42	61.13	23.12
17	1.048	.40	13	11.187	4.23	43	64.43	24.35
16	1.148	.44	14	11.936	4.51	44	67.89	25.66
−15	1.257	0.48	15	12.728	4.81	45	71.50	27.02
14	1.375	.52	16	13.565	5.13	46	75.28	28.46
13	1.506	.57	17	14.450	5.46	47	79.23	29.95
12	1.650	.62	18	15.383	5.82	48	83.36	31.51
11	1.806	.68	19	16.367	6.19	49	87.67	33.14
−10	1.974	0.75	20	17.406	6.58	50	92.17	34.84
9	2.154	.81	21	18.503	6.99	51	96.87	36.62
8	2.347	.89	22	19.661	7.43	52	101.77	38.47
7	2.557	.97	23	20.883	7.90	53	106.88	40.40
6	2.785	1.05	24	22.178	8.38	54	112.21	42.42
−5	3.032	1.15	25	23.546	8.90	55	117.77	44.52
4	3.299	1.25	26	24.987	9.45	56	123.56	46.71
3	3.586	1.36	27	26.505	10.02	57	129.59	48.98
2	3.894	1.47	28	28.103	10.62	58	135.87	51.36
1	4.223	1.60	29	29.785	11.26	59	142.41	53.83
0	4.579	1.73	30	31.555	11.93	60	149.21	56.40

* This table is quoted from "Smithsonian Meteorological Tables," p. 225.

RELATIVE DENSITY OF MOIST AIR FOR DIFFERENT PRESSURES AND HUMIDITIES.

TABLE 154. — Values of $\frac{h}{760}$, from $h = 1$ to $h = 9$, for the Computation of Different Values of the Ratio of Actual to Normal Barometric Pressure.

This gives the density of moist air at pressure h in terms of the density of the same air at normal atmosphere pressure. When air contains moisture, as is usually the case with the atmosphere, we have the following equation for pressure term: $h = B - 0.378e$, where e is the vapor pressure, and B the corrected barometric pressure. When the necessary psychrometric observations are made the value of e may be taken from Table 150, and then $0.378e$ from Table 153, or the dew-point may be found and the value of $0.378e$ taken from Table 153.

h	$\frac{h}{760}$
1	0.0013158
2	.0026316
3	.0039474
4	0.0052632
5	.0065789
6	.0078947
7	0.0092105
8	.0105263
9	.0118421

EXAMPLES OF USE OF THE TABLE.

To find the value of $\frac{h}{760}$ when $h = 754.3$

$h =$ 700	gives	.92105
50	"	.065789
4	"	.005263
.3	"	.000395
754.3		.992497

To find the value of $\frac{h}{760}$ when $h = 5.73$

$h =$ 5	gives	.0065789
.7	"	.0009210
.03	"	.0000395
5.73		.0075394

TABLE 155. — Values of the logarithms of $\frac{h}{760}$ for values of h between 80 and 340.

Values from 8 to 80 may be got by subtracting 1 from the characteristic, and from 0.8 to 8 by subtracting 2 from the characteristic, and so on.

h	Values of $\log \frac{h}{760}$.									
	0	1	2	3	4	5	6	7	8	9
80	$\bar{1}$.02228	$\bar{1}$.02767	$\bar{1}$.03300	$\bar{1}$.03826	$\bar{1}$.04347	$\bar{1}$.04861	$\bar{1}$.05368	$\bar{1}$.05871	$\bar{1}$.06367	$\bar{1}$.06858
90	.07343	.07823	.08297	.08767	.09231	.09691	.10146	.10596	.11041	.11482
100	$\bar{1}$.11919	$\bar{1}$.12351	$\bar{1}$.12779	$\bar{1}$.13202	$\bar{1}$.13622	$\bar{1}$.14038	$\bar{1}$.14449	$\bar{1}$.14857	$\bar{1}$.15261	$\bar{1}$.15661
110	.16058	.16451	.16840	.17226	.17609	.17988	.18364	.18737	.19107	.19473
120	.19837	.20197	.20555	.20909	.21261	.21611	.21956	.22299	.22640	.22978
130	.23313	.23646	.23976	.24304	.24629	.24952	.25273	.25591	.25907	.26220
140	.26531	.26841	.27147	.27452	.27755	.28055	.28354	.28650	.28945	.29237
150	$\bar{1}$.29528	$\bar{1}$.29816	$\bar{1}$.30103	$\bar{1}$.30388	$\bar{1}$.30671	$\bar{1}$.30952	$\bar{1}$.31231	$\bar{1}$.31509	$\bar{1}$.31784	$\bar{1}$.32058
160	.32331	.32601	.32870	.33137	.33403	.33667	.33929	.34190	.34450	.34707
170	.34964	.35218	.35471	.35723	.35974	.36222	.36470	.36716	.36961	.37204
180	.37446	.37686	.37926	.38164	.38400	.38636	.38870	.39128	.39334	.39565
190	.39794	.40022	.40249	.40474	.40699	.40922	.41144	.41365	.41585	.41804
200	$\bar{1}$.42022	$\bar{1}$.42238	$\bar{1}$.42454	$\bar{1}$.42668	$\bar{1}$.42882	$\bar{1}$.43094	$\bar{1}$.43305	$\bar{1}$.43516	$\bar{1}$.43725	$\bar{1}$.43933
210	.44141	.44347	.44552	.44757	.44960	.45162	.45364	.45565	.45764	.45963
220	.46161	.46358	.46554	.46749	.46943	.47137	.47329	.47521	.47712	.47902
230	.48091	.48280	.48467	.48654	.48840	.49025	.49210	.49393	.49576	.49758
240	.49940	.50120	.50300	.50479	.50658	.50835	.51012	.51188	.51364	.51539
250	$\bar{1}$.51713	$\bar{1}$.51886	$\bar{1}$.52059	$\bar{1}$.52231	$\bar{1}$.52402	$\bar{1}$.52573	$\bar{1}$.52743	$\bar{1}$.52912	$\bar{1}$.53081	$\bar{1}$.53249
260	.53416	.53583	.53749	.53914	.54079	.54243	.54407	.54570	.54732	.54894
270	.55055	.55216	.55376	.55535	.55694	.55852	.56010	.56167	.56323	.56479
280	.56634	.56789	.56944	.57097	.57250	.57403	.57555	.57707	.57858	.58008
290	.58158	.58308	.58457	.58605	.58753	.58901	.59048	.59194	.59340	.59486
300	$\bar{1}$.59631	$\bar{1}$.59775	$\bar{1}$.59919	$\bar{1}$.60063	$\bar{1}$.60206	$\bar{1}$.60349	$\bar{1}$.60491	$\bar{1}$.60632	$\bar{1}$.60774	$\bar{1}$.60914
310	.61055	.61195	.61334	.61473	.61611	.61750	.61887	.62025	.62161	.62298
320	.62434	.62569	.62704	.62839	.62973	.63107	.63240	.63373	.63506	.63638
330	.63770	.63901	.64032	.64163	.64293	.64423	.64553	.64682	.64810	.64939
340	.65067	.65194	.65321	.65448	.65574	.65701	.65826	.65952	.66077	.66201

DENSITY OF AIR.

Values of logarithms of $\frac{h}{760}$ for values of h between 350 and 800.

h	Values of log $\frac{h}{760}$.									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
350	$\bar{1}$.66325	$\bar{1}$.66449	$\bar{1}$.66573	$\bar{1}$.66696	$\bar{1}$.66819	$\bar{1}$.66941	$\bar{1}$.67064	$\bar{1}$.67185	$\bar{1}$.67307	$\bar{1}$.67428
360	.67549	.67669	.67790	.67909	.68029	.68148	.68267	.68385	.68503	.68621
370	.68739	.68856	.68973	.69090	.69206	.69322	.69437	.69553	.69668	.69783
380	.69897	.70011	.70125	.70239	.70352	.70465	.70577	.70690	.70802	.70914
390	.71025	.71136	.71247	.71358	.71468	.71578	.71688	.71798	.71907	.72016
400	$\bar{1}$.72125	$\bar{1}$.72233	$\bar{1}$.72341	$\bar{1}$.72449	$\bar{1}$.72557	$\bar{1}$.72664	$\bar{1}$.72771	$\bar{1}$.72878	$\bar{1}$.72985	$\bar{1}$.73091
410	.73197	.73303	.73408	.73514	.73619	.73723	.73828	.73932	.74036	.74140
420	.74244	.74347	.74450	.74553	.74655	.74758	.74860	.74961	.75063	.75164
430	.75265	.75366	.75467	.75567	.75668	.75768	.75867	.75967	.76066	.76165
440	.76264	.76362	.76461	.76559	.76657	.76755	.76852	.76949	.77046	.77143
450	$\bar{1}$.77240	$\bar{1}$.77336	$\bar{1}$.77432	$\bar{1}$.77528	$\bar{1}$.77624	$\bar{1}$.77720	$\bar{1}$.77815	$\bar{1}$.77910	$\bar{1}$.78005	$\bar{1}$.78100
460	.78194	.78289	.78383	.78477	.78570	.78664	.78757	.78850	.78943	.79036
470	.79128	.79221	.79313	.79405	.79496	.79588	.79679	.79770	.79861	.79952
480	.80043	.80133	.80223	.80313	.80403	.80493	.80582	.80672	.80761	.80850
490	.80938	.81027	.81115	.81203	.81291	.81379	.81467	.81554	.81642	.81729
500	$\bar{1}$.81816	$\bar{1}$.81902	$\bar{1}$.81989	$\bar{1}$.82075	$\bar{1}$.82162	$\bar{1}$.82248	$\bar{1}$.82334	$\bar{1}$.82419	$\bar{1}$.82505	$\bar{1}$.82590
510	.82676	.82761	.82846	.82930	.83015	.83099	.83184	.83268	.83352	.83435
520	.83519	.83602	.83686	.83769	.83852	.83935	.84017	.84100	.84182	.84264
530	.84346	.84428	.84510	.84591	.84673	.84754	.84835	.84916	.84997	.85076
540	.85158	.85238	.85319	.85399	.85479	.85558	.85638	.85717	.85797	.85876
550	$\bar{1}$.85955	$\bar{1}$.86034	$\bar{1}$.86113	$\bar{1}$.86191	$\bar{1}$.86270	$\bar{1}$.86348	$\bar{1}$.86426	$\bar{1}$.86504	$\bar{1}$.86582	$\bar{1}$.86660
560	.86737	.86815	.86892	.86969	.87047	.87123	.87200	.87277	.87353	.87430
570	.87506	.87582	.87658	.87734	.87810	.87885	.87961	.88036	.88111	.88186
580	.88261	.88336	.88411	.88486	.88560	.88634	.88708	.88782	.88856	.88930
590	.89004	.89077	.89151	.89224	.89297	.89370	.89443	.89516	.89589	.89661
600	$\bar{1}$.89734	$\bar{1}$.89806	$\bar{1}$.89878	$\bar{1}$.89950	$\bar{1}$.90022	$\bar{1}$.90094	$\bar{1}$.90166	$\bar{1}$.90238	$\bar{1}$.90309	$\bar{1}$.90380
610	.90452	.90523	.90594	.90665	.90735	.90806	.90877	.90947	.91017	.91088
620	.91158	.91228	.91298	.91367	.91437	.91507	.91576	.91645	.91715	.91784
630	.91853	.91922	.91990	.92059	.92128	.92196	.92264	.92333	.92401	.92469
640	.92537	.92604	.92672	.92740	.92807	.92875	.92942	.93009	.93076	.93143
650	$\bar{1}$.93210	$\bar{1}$.93277	$\bar{1}$.93343	$\bar{1}$.93410	$\bar{1}$.93476	$\bar{1}$.93543	$\bar{1}$.93609	$\bar{1}$.93675	$\bar{1}$.93741	$\bar{1}$.93807
660	.93873	.93939	.94004	.94070	.94135	.94201	.94266	.94331	.94396	.94461
670	.94526	.94591	.94656	.94720	.94785	.94849	.94913	.94978	.95042	.95106
680	.95170	.95233	.95297	.95361	.95424	.95488	.95551	.95614	.95677	.95741
690	.95804	.95866	.95929	.95992	.96055	.96117	.96180	.96242	.96304	.96366
700	$\bar{1}$.96428	$\bar{1}$.96490	$\bar{1}$.96552	$\bar{1}$.96614	$\bar{1}$.96676	$\bar{1}$.96738	$\bar{1}$.96799	$\bar{1}$.96861	$\bar{1}$.96922	$\bar{1}$.96983
710	.97044	.97106	.97167	.97228	.97288	.97349	.97410	.97471	.97531	.97592
720	.97652	.97712	.97772	.97832	.97892	.97951	.98012	.98072	.98132	.98191
730	.98251	.98310	.98370	.98429	.98488	.98547	.98606	.98665	.98724	.98783
740	.98842	.98900	.98959	.99018	.99076	.99134	.99193	.99251	.99309	.99367
750	$\bar{1}$.99425	$\bar{1}$.99483	$\bar{1}$.99540	$\bar{1}$.99598	$\bar{1}$.99656	$\bar{1}$.99713	$\bar{1}$.99771	$\bar{1}$.99828	$\bar{1}$.99886	$\bar{1}$.99942
760	0.00000	0.00057	0.00114	0.00171	0.00228	0.00285	0.00342	0.00398	0.00455	0.00511
770	.00568	.00624	.00680	.00737	.00793	.00849	.00905	.00961	.01017	.01072
780	.01128	.01184	.01239	.01295	.01350	.01406	.01461	.01516	.01571	.01626
790	.01681	.01736	.01791	.01846	.01901	.01955	.02010	.02064	.02119	.02173

TABLE 156.

VOLUME OF CASES.

Values of $1 + .00367\,t$.

The quantity $1 + .00367\,t$ gives for a gas the volume at t° when the pressure is kept constant, or the pressure at t° when the volume is kept constant, in terms of the volume or the pressure at 0°.

(a) This part of the table gives the values of $1 + .00367\,t$ for values of t between 0° and 10° C. by tenths of a degree.

(b) This part gives the values of $1 + .00367\,t$ for values of t between —90° and + 1990° C. by 10° steps.

These two parts serve to give any intermediate value to one tenth of a degree by a simple computation as follows:— In the (*b*) table find the number corresponding to the nearest lower temperature, and to this number add the decimal part of the number in the (*a*) table which corresponds to the difference between the nearest temperature in the (*b*) table and the actual temperature. For example, let the temperature be 682°.2:

We have for 680 in table (*b*) the number	3.49560
And for 2.2 in table (*a*) the decimal	.00807
Hence the number for 682.2 is	3.50367

(c) This part gives the logarithms of $1 + .00367\,t$ for values of t between —49° and + 399° C. by degrees.

(d) This part gives the logarithms of $1 + .00367\,t$ for values of t between 400° and 1990° C. by 10° steps.

(a) Values of $1 + .00387\,t$ for Values of t between 0° and 10° C. by Tenths of a Degree.

t	0.0	0.1	0.2	0.3	0.4
0	1.00000	1.00037	1.00073	1.00110	1.00147
1	.00367	.00404	.00440	.00477	.00514
2	.00734	.00771	.00807	.00844	.00881
3	.01101	.01138	.01174	.01211	.01248
4	.01468	.01505	.01541	.01578	.01615
5	1.01835	1.01872	1.01908	1.01945	1.01982
6	.02202	.02239	.02275	.02312	.02349
7	.02569	.02606	.02642	.02679	.02716
8	.02936	.02973	.03009	.03046	.03083
9	.03303	.03340	.03376	.03413	.03450

t	0.5	0.6	0.7	0.8	0.9
0	1.00184	1.00220	1.00257	1.00294	1.00330
1	.00550	.00587	.00624	.00661	.00697
2	.00918	.00954	.00991	.01028	.01064
3	.01284	.01321	.01358	.01395	.01431
4	.01652	.01688	.01725	.01762	.01798
5	1.02018	1.02055	1.02092	1.02129	1.02165
6	.02386	.02422	.02459	.02496	.02532
7	.02752	.02789	.02826	.02863	.02899
8	.03120	.03156	.03193	.03290	.03266
9	.03486	.03523	.03560	.03597	.03633

VOLUME OF GASES.

(b) Values of $1+.00367t$ for Values of t between $-90°$ and $+1990°$ C. by 10° Steps.

t	00	10	20	30	40
—000	1.00000	0.96330	0.92660	0.88990	0.85320
+000	1.00000	1.03670	1.07340	1.11010	1.14680
100	1.36700	1.40370	1.44040	1.47710	1.51380
200	1.73400	1.77070	1.80740	1.84410	1.88080
300	2.10100	2.13770	2.17440	2.21110	2.24780
400	2.46800	2.50470	2.54140	2.57810	2.61480
500	2.83500	2.87170	2.90840	2.94510	2.98180
600	3.20200	3.23870	3.27540	3.31210	3.34880
700	3.56900	3.60570	3.64240	3.67910	3.71580
800	3.93600	3.97270	4.00940	4.04610	4.08280
900	4.30300	4.33970	4.37640	4.41310	4.44980
1000	4.67000	4.70670	4.74340	4.78010	4.81680
1100	5.03700	5.07370	5.11040	5.14710	5.18380
1200	5.40400	5.44070	5.47740	5.51410	5.55080
1300	5.77100	5.80770	5.84440	5.88110	5.91780
1400	6.13800	6.17470	6.21140	6.24810	6.28480
1500	6.50500	6.54170	6.57840	6.61510	6.65180
1600	6.87200	6.90870	6.94540	6.98210	7.01880
1700	7.23900	7.27570	7.31240	7.34910	7.38580
1800	7.60600	7.64270	7.67940	7.71610	7.75280
1900	7.97300	8.00970	8.04640	8.08310	8.11980
2000	8.34000	8.37670	8.41340	8.45010	8.48680

t	50	60	70	80	90
—000	0.81650	0.77980	0.74310	0.70640	0.66970
+000	1.18350	1.22020	1.25690	1.29360	1.33030
100	1.55050	1.58720	1.62390	1.66060	1.69730
200	1.91750	1.95420	1.99090	2.02760	2.06430
300	2.28450	2.32120	2.35790	2.39460	2.43130
400	2.65150	2.68820	2.72490	2.76160	2.79830
500	3.01850	3.05520	3.09190	3.12860	3.16530
600	3.38550	3.42220	3.45890	3.49560	3.53230
700	3.75250	3.78920	3.82590	3.86260	3.89930
800	4.11950	4.15620	4.19290	4.22960	4.26630
900	4.48650	4.52320	4.55990	4.59660	4.63330
1000	4.85350	4.89020	4.92690	4.96360	5.00030
1100	5.22050	5.25720	5.29390	5.33060	5.36730
1200	5.58750	5.62420	5.66090	5.69760	5.73430
1300	5.95450	5.99120	6.02790	6.06460	6.10130
1400	6.32150	6.35820	6.39490	6.43160	6.46830
1500	6.68850	6.72520	6.76190	6.79860	6.83530
1600	7.05550	7.09220	7.12890	7.16560	7.20230
1700	7.42250	7.45920	7.49590	7.53260	7.56930
1800	7.78950	7.82620	7.86290	7.89960	7.93630
1900	8.15650	8.19320	8.22990	8.26660	8.30330
2000	8.52350	8.56020	8.59690	8.63360	8.67030

VOLUME OF

(c) Logarithms of 1 + .00367 *t* for Values

t	0	1	2	3	4	Mean diff. per degree.
−40	$\bar{1}$.931051	$\bar{1}$.929179	$\bar{1}$.927299	$\bar{1}$.925410	$\bar{1}$.923513	1884
−30	.949341	.947546	.945744	.943934	.942117	1805
−20	.966892	.965169	.963438	.961701	.959957	1733
−10	.983762	.982104	.980440	.978769	.977092	1667
−0	0.000000	.998403	.996801	.995192	.993577	1605
+0	0.000000	0.001591	0.003176	0.004755	0.006329	1582
10	.015653	.017188	.018717	.020241	.021760	1526
20	.030762	.032244	.033721	.035193	.036661	1474
30	.045362	.046796	.048224	.049648	.051068	1426
40	.059488	.060875	.062259	.063637	.065012	1381
50	0.073168	0.074513	0.075853	0.077190	0.078522	1335
60	.086431	.087735	.089036	.090332	.091624	1299
70	.099301	.100567	.101829	.103088	.104344	1259
80	.111800	.113030	.114257	.115481	.116701	1226
90	.123950	.125146	.126339	.127529	.128716	1191
100	0.135768	0.136933	0.138094	0.139252	0.140408	1158
110	.147274	.248408	.149539	.150667	.151793	1129
120	.158483	.159588	.160691	.161790	.162887	1101
130	.169410	.170488	.171563	.172635	.173705	1074
140	.180068	.181120	.182169	.183216	.184260	1048
150	0.190472	0.191498	0.192523	0.193545	0.194564	1023
160	.200632	.201635	.202635	.203634	.204630	1000
170	.210559	.211540	.212518	.213494	.214468	976
180	.220265	.221224	.222180	.223135	.224087	956
190	.229759	.230697	.231633	.232567	.233499	935
200	0.239049	0.239967	0.240884	0.241798	0.242710	916
210	.248145	.249044	.249942	.250837	.251731	897
220	.257054	.257935	.258814	.259692	.260567	878
230	.265784	.266648	.267510	.268370	.269228	861
240	.274343	.275189	.276034	.276877	.277719	844
250	0.282735	0.283566	0.284395	0.285222	0.286048	828
260	.290969	.291784	.292597	.293409	.294219	813
270	.299049	.299849	.300648	.301445	.302240	798
280	.306982	.307768	.308552	.309334	.310115	784
290	.314773	.315544	.316314	.317083	.317850	769
300	0.322426	0.323184	0.323941	0.324696	0.325450	756
310	.329947	.330692	.331435	.332178	.332919	743
320	.337339	.338072	.338803	.339533	.340262	730
330	.344608	.345329	.346048	.346766	.347482	719
340	.351758	.352466	.353174	.353880	.354585	707
350	0.358791	0.359488	0.360184	0.360879	0.361573	696
360	.365713	.366399	.367084	.367768	.368451	684
370	.372525	.373201	.373875	.374549	.375221	674
380	.379233	.379898	.380562	.381225	.381887	664
390	.385439	.386494	.387148	.387801	.388453	654

GASES.

of t between $-49°$ and $+399°$ C. by Degrees.

t	5	6	7	8	9	Mean diff. per degree.
−40	$\bar{1}$.921608	$\bar{1}$.919695	$\bar{1}$.917773	$\bar{1}$.915843	$\bar{1}$.913904	1926
−30	.940292	.938460	.936619	.934771	.932915	1845
−20	.958205	.956447	.954681	.952909	.951129	1771
−10	.975409	.973719	.972022	.970319	.968609	1699
−0	.991957	.990330	.988697	.987058	.985413	1636
+0	0.007897	0.009459	0.011016	0.012567	0.014113	1554
10	.023273	.024781	.026284	.027782	.029274	1500
20	.038123	.039581	.041034	.042481	.043924	1450
30	.052482	.053893	.055298	.056699	.058096	1402
40	.066382	.067748	.069109	.070466	.071819	1359
50	0.079847	0.081174	0.082495	0.083811	0.085123	1315
60	.092914	.094198	.095486	.096765	.098031	1281
70	.105595	.106843	.108088	.109329	.110566	1243
80	.117917	.119130	.120340	.121547	.122750	1210
90	.129899	.131079	.132256	.133430	.134601	1175
100	0.141559	0.142708	0.143854	0.144997	0.146137	1144
110	.152915	.154034	.155151	.156264	.157375	1115
120	.163981	.164072	.166161	.167246	.168330	1087
130	.174772	.175836	.176898	.177958	.179014	1060
140	.185301	.186340	.187377	.188411	.189443	1035
150	0.195581	0.196596	0.197608	0.198619	0.199626	1011
160	.205624	.206615	.207605	.208592	.209577	988
170	.215439	.216409	.217376	.218341	.219304	966
180	.225038	.225986	.226932	.227876	.228819	946
190	.234429	.235357	.236283	.237207	.238129	925
200	0.243621	0.244529	0.245436	0.246341	0.247244	906
210	.252623	.253512	.254400	.255287	.256172	887
220	.261441	.262313	.263184	.264052	.264919	870
230	.270085	.270940	.271793	.272644	.273494	853
240	.278559	.279398	.280234	.281070	.281903	836
250	0.286872	0.287694	0.288515	0.289326	0.290153	820
260	.295028	.295835	.296640	.297445	.298248	805
270	.303034	.303827	.304618	.305407	.306196	790
280	.310895	.311673	.312450	.313226	.314000	776
290	.318616	.319381	.320144	.320906	.321667	763
300	0.326203	0.326954	0.327704	0.328453	0.329201	750
310	.333659	.334397	.335135	.335871	.336606	737
320	.340989	.341715	.342441	.343164	.343887	724
330	.348198	.348912	.349624	.350337	.351048	713
340	.355289	.355991	.356693	.357394	.358093	701
350	0.362266	0.362957	0.363648	0.364337	0.365025	690
360	.369132	.369813	.370493	.371171	.371849	678
370	.375892	.376562	.377232	.377900	.378567	668
380	.382548	.383208	.383868	.384525	.385183	658
390	.389104	.389754	.390403	.391052	.391699	648

VOLUME OF GASES.

(d) Logarithms of 1 + .00367 *t* for Values of *t* between 400° and 1990° C. by 10° Steps.

t	00	10	20	30	40
400	0.392345	0.398756	0.405073	0.411300	0.417439
500	0.452553	0.458139	0.463654	0.469100	0.474479
600	.505421	.510371	.515264	.520103	.524889
700	.552547	.556990	.561388	.565742	.570052
800	.595055	.599086	.603079	.607037	.610958
900	.633771	.637460	.641117	.644744	.648341
1000	0.669317	0.672717	0.676090	0.679437	0.682759
1100	.702172	.705325	.708455	.711563	.714648
1200	.732715	.735655	.738575	.741475	.744356
1300	.761251	.764004	.766740	.769459	.772160
1400	.788027	.790616	.793190	.795748	.798292
1500	0.813247	0.815691	0.818120	0.820536	0.822939
1600	.837083	.839396	.841697	.843986	.846263
1700	.859679	.861875	.864060	.866234	.868398
1800	.881156	.883247	.885327	.887398	.889459
1900	.901622	.903616	.905602	.907578	.909545

t	50	60	70	80	90
400	0.423492	0.429462	0.435351	0.441161	0.446894
500	0.479791	0.485040	0.490225	0.495350	0.500415
600	.529623	.534305	.538938	.543522	.548058
700	.574321	.578548	.582734	.586880	.590987
800	.614845	.618696	.622515	.626299	.630051
900	.651908	.655446	.658955	.662437	.665890
1000	0.686055	0.689327	0.692574	0.695797	0.698996
1100	.717712	.720755	.723776	.726776	.729756
1200	.747218	.750061	.752886	.755692	.758480
1300	.774845	.777514	.780166	.782802	.785422
1400	.800820	.803334	.805834	.808319	.810790
1500	0.825329	0.827705	0.830069	0.832420	0.834758
1600	.848528	.850781	.853023	.855253	.857471
1700	.870550	.872692	.874824	.876945	.879056
1800	.891510	.893551	.895583	.897605	.899618
1900	.911504	.913454	.915395	.917327	.919251

DETERMINATION OF HEIGHTS BY THE BAROMETER.

Formula of Babinet: $Z = C\,\frac{B_0 - B}{B_0 + B}$.

C (in feet) $= 52494 \left[1 + \frac{t_0 + t - 64}{900}\right]$ English measures.

C (in meters) $= 16000 \left[1 + \frac{2\,(t_0 + t)}{1000}\right]$ metric measures.

In which Z = difference of height of two stations in feet or meters.

B_0, B = barometric readings at the lower and upper stations respectively, corrected for all sources of instrumental error.

t_0, t = air temperatures at the lower and upper stations respectively.

Values of C.

English Measures.			Metric Measures.		
$\frac{1}{2}(t_0+t)$.	C	Log C	$\frac{1}{2}(t_0+t)$.	C	Log C
Fahr.	Feet.		Cent.	Meters.	
10°	49928	4.69834	−10°	15360	4.18639
15	50511	.70339	−8	15488	.19000
			−6	15616	.19357
20	51094	4.70837	−4	15744	.19712
25	51677	.71330	−2	15872	.20063
30	52261	4.71818	0	16000	4.20412
35	52844	.72300	+2	16128	.20758
			4	16256	.21101
40	53428	4.72777	6	16384	.21442
45	54011	.73248	8	16512	.21780
50	54595	4.73715	10	16640	4.22115
55	55178	.74177	12	16768	.22448
			14	16896	.22778
60	55761	4.74633	16	17024	.23106
65	56344	.75085	18	17152	.23431
70	56927	4.75532	20	17280	4.23754
75	57511	.75975	22	17408	.24075
			24	17536	.24393
80	58094	4.76413	26	17664	.24709
85	58677	.76847	28	17792	.25022
90	59260	4.77276	30	17920	4.25334
95	59844	.77702	32	18048	.25643
			34	18176	.25950
100	60427	4.78123	36	18304	.26255

Values only approximate. Not good for great altitudes. A more accurate formula with corresponding tables may be found in Smithsonian Meteorological Tables, 3 revised ed. 1906.

BAROMETRIC

Barometric pressures corresponding to different
This table is useful when a boiling-point apparatus is used

(a) Common Measure.*

Temp. ° F.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
185	17.06	17.09	17.13	17.17	17.20	17.24	17.28	17.32	17.35	17.39
186	17.42	17.47	17.51	17.54	17.58	17.62	17.66	17.70	17.74	17.77
187	17.81	17.85	17.89	17.93	17.97	18.01	18.05	18.08	18.12	18.16
188	18.20	18.24	18.28	18.32	18.36	18.40	18.44	18.48	18.52	18.56
189	18.60	18.64	18.68	18.72	18.76	18.80	18.84	18.88	18.92	18.96
190	19.00	19.04	19.08	19.12	19.16	19.21	19.25	19.29	19.33	19.37
191	19.41	19.45	19.49	19.54	19.58	19.62	19.66	19.70	19.75	19.79
192	19.83	19.87	19.91	19.96	20.00	20.04	20.08	20.13	20.17	20.21
193	20.26	20.30	20.34	20.38	20.43	20.47	20.51	20.56	20.60	20.64
194	20.68	20.73	20.78	20.82	20.86	20.91	20.95	20.99	21.04	21.08
195	21.13	21.17	21.22	21.26	21.31	21.35	21.40	21.44	21.48	21.53
196	21.58	21.62	21.67	21.71	21.76	21.80	21.85	21.90	21.94	21.99
197	22.03	22.08	22.13	22.17	22.22	22.27	22.31	22.36	22.41	22.45
198	22.50	22.55	22.59	22.64	22.69	22.73	22.78	22.83	22.88	22.92
199	22.97	23.02	23.07	23.12	23.16	23.21	23.26	23.31	23.36	23.40
200	23.45	23.50	23.55	23.60	23.65	23.70	23.75	23.79	23.84	23.89
201	23.94	23.99	24.04	24.09	24.14	24.19	24.24	24.29	24.34	24.39
202	24.44	24.49	24.54	24.59	24.64	24.69	24.74	24.79	24.85	24.90
203	24.95	25.00	25.05	25.10	25.15	25.20	25.26	25.31	25.36	25.41
204	25.46	25.52	25.57	25.62	25.67	25.72	25.78	25.83	25.88	25.94
205	25.99	26.04	26.09	26.15	26.20	26.25	26.31	26.36	26.41	26.47
206	26.52	26.58	26.63	26.68	26.74	26.79	26.85	26.90	26.96	27.01
207	27.06	27.12	27.17	27.23	27.28	27.34	27.39	27.45	27.51	27.56
208	27.62	27.67	27.73	27.78	27.84	27.90	27 95	28.01	28.07	28.12
209	28.18	28.24	28.29	28.35	28.41	28.46	28.52	28.58	28.63	28.69
210	28.75	28.81	28.87	28.92	28.98	29.04	29.10	29.16	29.21	29.27
211	29.33	29.39	29.45	29.51	29.57	29.63	29.68	29.74	29.80	29.86
212	29.92	29.98	30.04	30.10	30.16	30.22	30.28	30.34	30.40	30.46

* Pressures in inches of mercury.

The values at the lower temperatures are perhaps ½% too low. Table (b) is based on more recent data (1913).

temperatures of the boiling-point of water.
in place of the barometer for the determination of heights.

(b) Metric Measure.*

Temp. ° C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
80°	355.5	356.9	358.4	359.8	361.3	362.7	364.2	365.7	367.1	368.6
81	370.1	371.6	373.1	374.6	376.1	377.6	379.1	380.6	382.2	383.7
82	385.2	386.8	388.3	389.9	391.4	393.0	394.6	396.2	397.7	399.3
83	400.9	402.5	404.1	405.7	407.3	408.9	410.5	412.2	413.8	415.4
84	417.1	418.7	420.4	422.0	423.7	425.4	427.0	428.7	430.4	432.1
85	433.8	435.5	437.2	438.9	440.6	442.4	444.1	445.8	447.6	449.3
86	451.1	452.8	454.6	456.4	458.1	459.9	461.7	463.5	465.3	467.1
87	468.9	470.7	472.5	474.4	476.2	478.0	479.9	481.7	483.6	485.5
88	487.3	489.2	491.1	493.0	494.9	496.8	498.7	500.6	502.5	504.4
89	506.4	508.3	510.2	512.2	514.1	516.1	518.1	520.0	522.0	524.0
90	526.0	528.0	530.0	532.0	534.0	536.0	538.1	540.1	542.2	544.2
91	546.3	548.3	550.4	552.5	554.6	556.6	558.7	560.8	563.0	565.1
92	567.2	569.3	571.4	573.6	575.7	577.9	580.1	582.2	584.4	586.6
93	588.8	591.0	593.2	595.4	597.6	599.8	602.0	604.3	606.5	608.8
94	611.0	613.3	615.6	617.8	620.1	622.4	624.7	627.0	629.4	631.7
95	634.0	636.3	638.7	641.0	643.4	645.8	648.1	650.5	652.9	655.3
96	657.7	660.1	662.5	664.9	667.4	669.8	672.2	674.7	677.2	679.6
97	682.1	684.6	687.1	689.6	692.1	694.6	697.1	699.6	702.2	704.7
98	707.3	709.8	712.4	715.0	717.6	720.2	722.8	725.4	728.0	730.6
99	733.2	735.9	738.5	741.2	743.8	746.5	749.2	751.9	754.6	757.3
100	760.0	762.7	765.4	768.2	770.9	773.7	776.4	779.2	782.0	784.8

* Pressure in millimeters of mercury.

STANDARD WAVE-LENGTHS.

TABLE 159. — Absolute Wave-length of Red Cadmium Line in Air, 760 mm. Pressure, 15° C.

6438.4722 Michelson, Travaux et Mém. du Bur. intern. des Poids et Mesures, 11, 1895.
6438.4700 Michelson, corrected by Benoit, Fabry, Perot, C. R. 144, 1082, 1907.
6438.4696 (accepted primary standard) Benoit, Fabry, Perot, C. R. 144, 1082, 1907.

TABLE 160. — International Secondary Standards. Iron Arc Lines.

Adopted as secondary standards at the International Union for Coöperation in Solar Research (transactions, 1910). Means of measures of Fabry-Buisson (1), Pfund (2), and Eversheim (3). Referred to primary standard = Cd. line, λ = 6438.4696 Ångströms (serving to define an Ångström). 760 mm., 15° C. Iron rods, 7 mm. diam. length of arc, 6 mm.; 6 amp. for λ greater than 4000 Ångströms, 4 amp. for lesser wave-lengths; continuous current, + pole above the —, 220 volts; source of light, 2 mm. at arc's center. Lines adopted in 1910.

Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.
4282.408	4547.853	4789.657	5083.344	5405.780	5615.661	6230.734
4315.089	4592.658	4878.225	5110.415	5434.527	5658.836	6265.145
4375.934	4602.947	4903.325	5167.492	5455.614	5763.013	6318.028
4427.314	4647.439	4919.007	5192.363	5497.522	6027.059	6335.341
4466.556	4691.417	5001.881	5232.957	5506.784	6065.492	6393.612
4494.572	4707.288	5012.073	5266.569	5569.633	6137.701	6430.859
4531.155	4736.786	5049.827	5371.495	5586.772	6191.568	6494.993

TABLE 161. — International Secondary Standards. Iron Arc Lines.

Adopted in 1913. (4) Means of measures of Fabry-Buisson, Pfund, Burns and Eversheim.

Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.	Wave-length.
3370.789	3606.682	3753.615	3906.482	4076.642	4233.615	6750.250
3399.337	3640.392	3805.346	3907.937	4118.552	5709.396	5857.759 Ni
3485.345	3676.313	3843.261	3935.818	4134.685	6546.250	5892.882 Ni
3513.821	3677.629	3850.820	3977.746	4147.676	6592.928	
3556.881	3724.380	3865.527	4021.872	4191.443	6678.004	

(1) Astrophysical Journal, 28, p. 169, 1908; (2) Ditto, 28, p. 197, 1908; (3) Annalen der Physik, 30, p. 815, 1909. See also Eversheim, *ibid.* 36, p. 1071, 1911; Buisson et Fabry, *ibid.* 38, p. 245, 1912; (4) Astrophysical Journal, 39, p. 93, 1914.

TABLE 162. — Some of the Stronger Lines of Some of the Elements.

Barium .	5535.7	Helium .	5875.8	Magnesium	5167.5	Sodium .	5890.2
Cæsium .	4555.4	" . .	5876.2	" . .	5172.9	" . .	5896.2
" .	4593.3	Hydrogen	4101.8	" . .	5183.8	Strontium	4607.5
Calcium .	5589.0	" . .	4340.7	Mercury .	5461.0	" . .	5481.2
Cadmium	4799.9	" . .	4861.5	Potassium .	7668.5	" . .	6408.6
" . .	5085.8	" . .	6563.0	" . .	7701.9	Thallium.	5350.6
" . .	6438.5	Lithium .	6708.2	Rubidium .	6298.7		

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-lengths are in Ångström units (10^{-7} mm.), in air at 20° C and 76 cm. of mercury pressure. The intensities run from 1, just clearly visible on the map, to 1000 for the H and K lines; below 1 in order of faintness to 0000 as the lines are more and more difficult to see. This table contains only the lines above 5.

N indicates a line not clearly defined, probably an undissolved multiple line; s, a faded appearing line; d, a double. In the "substance" column, where two or more elements are given, the line is compound; the order in which they are given indicates the portion of the line due to each element; when the solar line is too strong to be due wholly to the element given, it is represented, –Fe, for example; when commas separate the elements instead of a dash, the metallic lines coincide with the same part of the solar line, Fe, Cr, for example.

Capital letters next the wave-length numbers are the ordinary designations of the lines. A indicates atmospheric lines, (wv), due to water vapor, (O), due to Oxygen.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
3037.510s	Fe	10 N	3372.947	Ti–Pd	10 d?	3533.345	Fe	6
3047.725s	Fe	20 N	3380.722	Ni	6 N	3536.709	Fe	7
3053.530s	–	7 d?	3414.911	Ni	15	3541.237	Fe	7
3054.429	Mn, Ni	10	3423.848	Ni	7	3542.232	Fe	6
3057.552s	Ti, Fe	20	3433.715	Ni, Cr	8 d?	3555.079	Fe	9
3059.212s	Fe	20	3440.762s } O	Fe	20	3558.672s	Fe	8
3067.369s	Fe	8	3441.155s } O	Fe	15	3565.535s	Fe	20
3073.091	Ti, –	6 Nd?	3442.118	Mn	6	3566.522	Ni	10
3078.769s	Ti, –	8 d?	3444.020s	Fe	8 N	3570.273s	Fe	20
3088.145s	Ti	7 d?	3446.406	Ni	15	3572.014	Ni	6
3134.230s	Ni, Fe	8	3449.583	Co	6 d?	3572.712	Se, –	6
3188.656	–, Fe	6 d?	3453.039	Ni	6 d?	3578.832	Cr	10
3236.703s	Ti	7 N	3458.601	Ni	8	3581.349s	Fe	30
3239.170	Ti	7	3461.801	Ni	8	3584.800	Fe	6
3242.125	Ti, –	8	3462.950	Co	6	3585.105	Fe	6
3243.189	–, Ni	6	3466.015s	Fe	6	3585.479	Fe	7
3247.688s	Cu	10	3475.594s	Fe	10	3585.859	Fe	6
3256.021	Fe?	6	3476.849s	Fe	8	3587.130	Fe	8
3267.834s	V	6	3483.923	Ni	6 d?	3587.370	Co	7
3271.129	Fe	6	3485.493	Fe Co	6	3588.084	Ni	6
3271.791	Ti, Fe	6 d?	3490.733s	Fe	10 N	3593.636	Cr	9
3274.096s	Cu	10	3493.114	Ni	10 N	3594.784	Fe	6
3277.482	Co–Fe	7 d?	3497.982s	Fe	8	3597.854	Ni	8
3286.898	Fe	7 N	3500.996s	Ni	6 d?	3605.479s	Cr	7
3295.951s	Fe, Mn	6	3510.466	Ni	8	3606.838s	Fe	6
3302.510s	Na	6	3512.785	Co	6	3609.008s	Fe	20
3315.807	Ni	7 d?	3513.965s	Fe	7	3612.882	Ni	6 d?
3318.160s	Ti	6	3515.206	Ni	12	3617.934s	Fe	6
3320.391	Ni	7	3519.904	N	7	3618.919s	Fe	20
3336.820	Mg	8 N	3521.410s	Fe	8	3619.539	Ni	8
3349.597	Ti	7	3524.677	Ni	20	3621.612s	Fe	6
3361.327	Ti	8	3526.183	Fe	6	3622.147s	Fe	6
3365.908	Ni	6	3526.988	Co	6	3631.605s	Fe	15
3366.311	Ti, Ni	6 d?	3529.964	Fe–Co	6	3640.535s	Cr–Fe	6
3369.713	Fe, Ni	6	3533.156	Fe	6	3642.820	Ti	7

Corrections to reduce Rowland's wave-lengths to standards of Table 160 (the accepted standards, 1913). Temperature 15° C, pressure 760 mm.

The differences "(Fabry-Buisson-arc-iron) — (Rowland-solar-iron)" lines were plotted, a smooth curve drawn, and the following values obtained:

Wave-length	3000.	3100.	3200.	3300.	3400.	3500.	3600.	3700.
Correction	—.106	—.115	—.124	—.137	—.148	—.154	—.155	—.140

H. A. Rowland, "A preliminary table of solar-spectrum wave-lengths," Astrophysical Journal, 1–6, 1895–1897.

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
3647.988s	Fe	12	3826.027s	Fe	20	4045.975s	Fe	30
3651.247	Fe,–	6	3827.980	Fe	8	4055.701s	Mn	6
3651.614	Fe	7	3829.501s	Mg	10	4057.668	–	7
3676.457	Fe, Cr	6	3831.837	Ni	6	4063.759s	Fe	20
3680.069s	Fe	9	3832.450s	Mg	15	4068.137	Fe–Mn	6
3684.258s	Fe	7d?	3834.364	Fe	10	4071.908s	Fe	15
3685.339	Ti	10d?	3838.435s	Mg–C	25	4077.885s	Sr	8
3686.141	Ti–Fe	6	3840.580s	Fe–C	8	4102.000Hδ	H, In	40N
3687.610s	Fe	6	3841.195	Fe–Mn	10	4121.477s	Cr–Co	6d?
3689.614	Fe	6	3845.606	C–Co	8d?	4128.251	Ce–V,–	6d
3701.234	Fe	8	3850.118	Fe–Cr	10	4132.235	Fe–Co	10
3705.708s	Fe	9	3856.524s	Fe	8	4137.156	Fe	6
3706.175	Ca, Mn	6d?	3857.805	Cr–C	6d?	4140.089	Fe	6
3709.389s	Fe	8	3858.442	Ni	7	4144.038	Fe	15
3716.591s	Fe	7	3860.055s	Fe–C	20	4167.438	–	8
3720.084s	Fe	40	3865.674	Fe–C	7	4187.204	Fe	6
3722.692s	Ni	10	3872.639	Fe	6	4191.595	Fe	6
3724.526	Fe	6	3878.152	Fe–C	8	4202.198s	Fe	8
3732.545s	Co–Fe	6	3878.720	Fe	7Nd?	4226.904sg	Ca	20d?
3733.469s	Fe–	7d?	3886.434s	Fe	15	4233.772	Fe	6
3735.014s	Fe	40	3887.196	Fe	7	4236.112	Fe	8
3737.281s	Fe	30	3894.211	–	8d	4250.287s	Fe	8
3738.466	·	6	3895.803	Fe	7	4250.945s	Fe	8
3743.508	Fe–Ti	6	3899.850	Fe	8	4254.505s	Cr	8
3745.717s	Fe	8	3903.090	Cr, Fe, Mo	10	4260.640s	Fe	10
3746.058s	Fe	6	3904.023	–	8d	4271.934s	Fe	15
3748.408s	Fe	10	3905.660s	Si	12	4274.958s	Cr	7d?
3749.631s	Fe	20	3906.628	Fe	10	4308.081sG	Fe	6
3753.732	Fe–Ti	6d?	3920.410	Fe	10	4325.939s	Fe	8
3758.375s	Fe	15	3923.054	Fe	12d?	4340.634Hγ	H	20N
3759.447	Ti	12d?	3928.075s	Fe	8	4376.107s	Fe	6
3760.196	Fe	5	3930.450	Fe	8	4383.720s	Fe	15
3761.464	Ti	7	3933.523	–	8N	4404.927s	Fe	10
3763.945s	Fe	10	3933.825sK	Ca	1000	4415.293s	Fe	8
3765.689	Fe	6	3934.108	Co, V–Cr	8N	4442.510	Fe	6
3767.341s	Fe	8	3944.160s	Al	15	4447.892s	Fe	6
3775.717	Ni	7	3956.819	Fe	6	4494.738s	Fe	6
3783.674s	Ni	6	3957.177s	Fe–Ca	7d?	4528.798	Fe	8
3788.046s	Fe	9	3961.674s	Al	20	4534.139	Ti–Co	6
3795.147s	Fe	8	3968.350	–, Zr	6N	4549.808	Ti–Co	6d?
3798.655s	Fe	6	3968.625sH	Ca	700	4554.211s	Ba	8
3799.693s	Fe	7	3968.886	–	6N	4572.156s	Ti–	6
3805.486s	Fe	6	3969.413	Fe	10	4603.126	Fe	6
3806.865	Mn–Fe	8d?	3974.904	Co–Fe	6d?	4629.521s	Ti–Co	6
3807.293	Ni	6	3977.891s	Fe	6	4679.027s	Fe	6
3807.681	V–Fe	6	3986.903s	–	6	4703.177s	Mg	10
3814.698	–	8	4005.408	Fe	7	4714.599s	Ni	6
3815.987s	Fe	15	4030.918s	Mn	10d?	4736.963	Fe	6
3820.586sL	Fe–C	25	4033.224s	Mn	8d?	4754.225s	Mn	7
3824.591	Fe	6	4034.644s	Mn	6d	4783.613s	Mn	6

Corrections to reduce Rowland's wave-lengths to standards of Table 160 (the accepted standards, 1913). Temperature 15° C, pressure 760 mm.:

Wave-length	3600.	3700.	3800.	3900.	4000.	4100.	4200.	4300.	4400.	4500.	4600.	4700.	4800.
Correction	—.155	—.140	—.141	—.144	—.148	—.152	—.156	—.161	—.167	—.172	—.176	—.179	—.179.

TABLE 163 (*continued*).

STANDARD SOLAR WAVE-LENGTHS. ROWLAND'S VALUES.

Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.	Wave-length.	Substance.	Intensity.
4861.527sF	H	30	5948.765s	Si	6	6563.045sC	H	40
4890.948s	Fe	6	5985.040s	Fe	6	6593.161s	Fe	6
4891.683	Fe	8	6003.239s	Fe	6	6867.457sB	A(O)	6d?
4919.174s	Fe	6	6008.785s	Fe	6	6868.336 } s	A(O)	6
4920.685	Fe	10	6013.715s	Mn	6	6868.478 } s	A(O)	6
4957.785s	Fe	8	6016.861s	Mn	6	6869.142s	A(O)	7
5050.008s	Fe	6	6022.016s	Mn	6	6869.353s	A(O)	6
5167.497sb$_4$	Mg	15	6024.281s	Fe	7	6870.116 } s	A(O)	7 } d
5171.778s	Fe	6	6065.709s	Fe	7	6870.249 } s	A(O)	7 } d
5172.856sb$_2$	Mg	20	6102.392s	Fe	6	6871.180s	A(O)	8
5183.791sb$_1$	Mg	30	6102.937s	Ca	9	6871.532s	A(O)	10
5233.122s	Fe	7	6108.334s	Ni	6	6872.486s	A(O)	11
5266.738s	Fe	6	6122.434s	Ca	10	6873.080s	A(O)	12
5269.723sE	Fe	8d?	6136.829s	Fe	8	6874.037s	A(O)	12
5283.802s	Fe	6	6137.915	Fe	7	6874.899s	A(O)	13
5324.373s	Fe	7	6141.938s	Fe, Ba	7	6875.830s	A(O)	13
5328.236	Fe	8d?	6155.350	–	7	6876.958s	A(O)	13
5340.121	Fe	6	6162.390s	Ca	15	6877.882s	A(O)	12
5341.213	Fe	7	6169.249s	Ca	6	6879.288s	A(O)	12
5367.669s	Fe	6	6169.778s	Ca	7	6880.172s	A(O)	6
5370.166s	Fe	6	6170.730	Fe–Ni	6	6884.076s	A(O)	10
5383.578s	Fe	6	6191.393s	Ni	6	6886.000s	A(O)	11
5397.344s	Fe	7d?	6191.779s	Fe	9	6886.990s	A(O)	12
5405.989s	Fe	6	6200.527s	Fe	6	6889.192s	A(O)	13
5424.290s	Fe	6	6213.644s	Fe	6	6890.151s	A(O)	14
5429.911	Fe	6d?	6219.494s	Fe	6	6892.618s	A(O)	14
5447.130s	Fe	6d?	6230.943s	V–Fe	8	6893.560s	A(O)	15
5528.641s	Mg	8	6246.535s	Fe	8	6896.289s	A(O)	14
5569.848	Fe	6	6252.773s	–Fe	7	6897.208s	A(O)	15
5573.075	Fe	6	6256.572s	Ni–Fe	6	6900.199s	A(O)	14
5586.991	Fe	7	6301.718	Fe	7	6901.117s	A(O)	15
5588.985s	Ca	6	6318.239	Fe	6	6904.362s	A(O)	14
5615.877s	Fe	6	6335.554	Fe	6	6905.271s	A(O)	14
5688.436s	Na	6	6337.048	Fe	7	6908.783s	A(O)	13
5711.313s	Mg	6	6358.898	Fe	6	6909.676s	A(O)	13
5763.218s	Fe	6	6393.820s	Fe	7	6913.448s	A(O)	11
5857.674s	Ca	8	6400.217s	Fe	8	6914.337s	A(O)	11
5862.582s	Fe	6	6411.865s	Fe	7	6918.370s	A(O)	9
5890.186sD$_2$	Na	30	6421.570s	Fe	7	6919.250s	A(O)	9
5896.155 D$_1$	Na	20	6439.293s	Ca	8	6923.553s	A(O)	9
5901.682s	A(wv)	6	6450.033s	Ca	6	6924.427s	A(O)	9
5914.430s	–, A(wv)	6	6494.004s	Ca	6	7191.755	A, –	6N
5919.860s	A(wv)	7	6495.213	Fe	8	7206.692	–, A	6
5930.406s	Fe	6	6546.479s	Ti–Fe	6			

Corrections to reduce Rowland's wave-lengths to standards of Table 160 (the accepted standards, 1913). Temperature 15° C, pressure 760 mm.:

Wave-length	4800.	4900.	5000.	5100.	5200.	5300.	5400.	5500.	5600.	5700.	5800.
Correction	—.179	—.176	—.173	—.170	—.166	—.172	—.212	—.217	—.218	—.213	—.209

Wave-length	5800.	5900.	6000.	6100.	6200.	6300.	6400.	6500.	6600.	6700.	6800.
Correction	—.209	—.209	—.213	—.214	—.213	—.210	—.209	—.210.			

TABLE 164.

TERTIARY STANDARD WAVE-LENGTHS. IRON ARC LINES.

For arc conditions see Table 160, p. 172. For lines of group *c* class 5 for best results the slit should be at right angles to the arc at its middle point and the current should be reversed several times during the exposure.

Wave-lengths.	Class.	Intensity.	Wave-lengths.	Class.	Intensity.	Wave-lengths.	Class.	Intensity.
*2781.840		4	4337.052	b3	5	5332.909	a4	2
*2806.985		7	4369.777	b3	3	5341.032	a4	5
*2831.559		3	4415.128	b1	8r	5365.404	a1	2
*2858.341		3	4443.198	b3	3	5405.780	a	6
*2901.382		4	4461.658	a3	4	5434.528	a	6
*2926.584		5	4489.746	a3	3	5473.913	a	4
*2986.460		3	4528.620	c4	7	5497.521	a	4
*3000.453		4	4619.297	c4	4	5501.471	a	4
*3053.070		4	4786.811	c4	3	5506.784	a	3
*3100.838		2	4871.331	c5	8	‡5535.419	a	2
*3154.202		4	4890.769	c5	7	5563.612	b	3
*3217.389		4	4924.773	a	3	5975.352	b	2
*3257.603		4	4939.685	a	3	6027.059	b	3
*3307.238		4	4973.113	a	2	6065.495	b	4
*3347.932		4	4994.133	a	3	6136.624	b	5
*3389.748		3	5041.076	a	3	6157.734	b	4
*3476.705		5	5041.760	a	4	6165.370	b	3
*3506.502		5	5051.641	a	4	6173.345	b	4
*3553.741		5	5079.227	a	3	6200.323	b	4
*3617.789		6	5079.743	a	3	6213.441	b	5
*3659.521		5	5098.702	a	4	6219.290	b	5
*3705.567		6R	5123.729	a	4	6252.567	b	6
*3749.487		8R	5127.366	a	3	6254.269	b	4
*3820.430		8R	5150.846	a	4	6265.145	b	5
*3859.913		7R	5151.917	a	3	6297.802	b	4
*3922.917		6R	5194.950	a	5	6335.342	b	6
*3956.682		6	5202.341	a	5	6430.859	b	5
*4009.718		5	5216.279	a	5	6494.992	b	6
*4062.451		4	5227.191	a4	8			
†4132.063	b1	7	5242.495	a	3			
†4175.639	b	4	5270.356	a4	8			
†4202.031	b1	7r	5328.043	a1	7			
†4250.791	b2	7	5328.537	a4	4			

* Measures of Burns. † Means of St. John and Burns.
‡ Means of St. John and Goos. Others are means of measures by all three. References: St. John and Ware, Astrophysical Journal, 36, 1912; 38, 1913; Burns, Z. f. wissen. Photog. 12, p. 207, 1913, J. de Phys. 1913, and unpublished data; Goos, Astrophysical Journal, 35, 1912; 37, 1913. The lines in the table have been selected from the many given in these references with a view to equal distribution and where possible of classes *a* and *b*.

For class and pressure shifts see Gale and Adams, Astrophysical Journal, 35, p. 10, 1912. Class *a:* "This involves the well-known flame lines (de Watteville, Phil. Trans. A 204, p. 139. 1904), i.e. the lines relatively strengthened in low-temperature sources, such as the flame of the arc, the low-current arc, and the electric furnace. (Astrophysical Journal, 24, p. 185, 1906, 30, p. 86, 1909, 34, p. 37, 1911, 35, p. 185, 1912.) The lines of this group in the yellow-green show small but definite pressure displacements, the mean being 0.0036 Ångström per atmosphere in the arc." Class *b:* "To this group many lines belong; in fact all the lines of moderate displacement under pressure are assigned to it for the present. These are bright and symmetrically widened under pressure, and show mean pressure displacements of 0.009 Ångström per atmosphere for the lines in the region λ 5975–6678 according to Gale and Adams. Group *c* contains lines showing much larger displacements. The numbers in the class column have the following meaning: 1, symmetrically reversed; 2, unsymmetrically reversed; 3, remain bright and fairly narrow under pressure; 4, remain bright and symmetrical under pressure but become wide and diffuse; 5, remain bright and are widened very unsymmetrically toward the red under pressure."

For further measures in International units see Kayser, Bericht über den gegenwärtigen Stand der Wellenlängenmessungen, International Union for Coöperation in Solar Research, 1913. For further spectroscopic data see Kayser's Handbuch der Spectroscopie.

WAVE-LENGTHS OF FRAUNHOFER LINES.

For convenience of reference the values of the wave-lengths corresponding to the Fraunhofer lines usually designated by the letters in the column headed "index letters," are here tabulated separately. The values are in ten millionths of a millimeter, on the supposition that the D line value is 5896.155. The table is for the most part taken from Rowland's table of standard wave-lengths.

Index Letter.	Line due to —	Wave-length in centimeters × 10⁸.	Index Letter.	Line due to —	Wave-length in centimeters × 10⁸.
A	O	7621.28*	G	Fe	4308.081
	O	7594.06*		Ca	4307.907
a	-	7164.725	g	Ca	4226.904
B	O	6870.182 †	h or H_δ	H	4102.000
C or H_α	H	6563.045	H	Ca	3968.625
α	O	6278.303 ‡	K	Ca	3933.825
D_1	Na	5896.155	L	Fe	3820.586
D_2	Na	5890.186	M	Fe	3727.778
D_3	He	5875.985	N	Fe	3581.349
E_1	Fe	5270.558	O	Fe	3441.155
	Ca	5270.438	P	Fe	3361.327
E_2	Fe	5269.723	Q	Fe	3286.898
b_1	Mg	5183.791	R	Ca	3181.387
b_2	Mg	5172.856		Ca	3179.453
b_3	Fe	5169.220	S_1, S_2	Fe	3100.787
	Fe	5169.069		Fe	3100.430
b_4	Fe	5167.678		Fe	3100.046
	Mg	5167.497	s	Fe	3047.725
F or H_β	H	4861.527	T	Fe	3020.76
d	Fe	4383.721	t	Fe	2994.53
G′ or H_γ	H	4340.634	U	Fe	2947.99
f	Fe	4325.939			

* The two lines here given for A are stated by Rowland to be: the first, a line "beginning at the head of A, outside edge;" the second, a "single line beginning at the tail of A."
† The principal line in the head of B.
‡ Chief line in the α group.
See Table 163, Rowland's Solar Wave-lengths (foot of page) for correction to reduce these values to standard system of wave-lengths, Table 160.

TABLE 166.—Photometric Standards.

No primary photometric standard has been generally adopted by the various governments. In Germany the Herner lamp is most used; in England the Pentane lamp and sperm candles are used; in France the Carcel lamp is preferred; in America the Pentane and Hefner lamps are used to some extent, but candles are more largely employed in gas photometry. For the photometry of electric lamps, and generally in accurate photometric work, electric lamps, standardized at a national standardizing institution, are commonly employed.

The "International candle" is the name recently employed to designate the value of the candle as maintained by coöperative effort between the national laboratories of England, France, and America; and the value of various photometric units in terms of this international candle is given in the following table (taken from Circular No. 15 of the Bureau of Standards).

1 International Candle = 1 Pentane Candle.
1 International Candle = 1 Bougie Decimale.
1 International Candle = 1 American Candle.
1 International Candle = 1.11 Hefner Unit.
1 International Candle = 0.104 Carcel Unit.

Therefore 1 Hefner Unit = 0.90 International Candle.

The values of the flame standards most commonly used are as follows:

1. Standard Pentane Lamp, burning pentane . . . . 10.0 candles.
2. Standard Hefner Lamp, burning amyl acetate . . . . . 0.9 candles.
3. Standard Carcel Lamp, burning colza oil . . . . 9.6 candles.
4. Standard English Sperm Candle, approximately . . . . 1.0 candles.

Slight differences in candle power are found in different lamps, even when made as accurately as possible to the same specifications. Hence these so-called primary standards should be themselves standardized.

TABLE 167.—Intrinsic Brightness of Various Light Sources.

	Barrows.	Ives & Luckiesh.		National Electric Lamp Association.
	C. P. per Sq. In. of surface of light.	C. P. per Sq. In. of surface of light.	C. P. per Sq. Mm. of surface of light.	C. P. per Sq. In. of surface of light.
Sun at Zenith	600,000			600,000
Crater, carbon arc	200,000	84,000	130.	200,000
Open carbon arc	10,000–50,000	–	–	10,000–50,000
Flaming arc	5,000		–	5,000
Magnetite arc	–	4,000	6.2	–
Nernst Glower	800–1,000	(115v.6 amp. d.c.) 3,010	4.7	(1.5 w.p.c.) 2,200
Tungsten incandescent, 1.15 w. p. c.	..	–	–	1,000
Tungsten incandescent, 1.25 w. p. c.	1,000	1,000	1.64	875
Tantalum incandescent, 2.0 w. p. c.	750	580	0.9	750
Graphitized carbon filament, 2.5 w. p. c.	625	750	1.2	625
Carbon incandescent, 3.1 w. p. c.	480	485	0.75	480
Carbon incandescent, 3.5 w. p. c.	375	400	0.63	375
Carbon incandescent, 4.0 w. p. c.	300	325	0.50	–
Inclosed carbon arc (d. c.)	100–500	–	–	100–500
Inclosed carbon arc (a. c.)	–		–	75–200
Acetylene flame (1 ft. burner)	75–100	53.0	0.082	75–100
Acetylene flame (¼ ft. burner)	–	33.0	0.057	–
Welsbach mantle	20–25	31.9	0.048	20–50
Welsbach (mesh)	–	56.0	0.067	–
Cooper Hewitt mercury vapor lamp	16.7	14.9	0.023	17
Kerosene flame	4–8	9.0	0.014	3–8
Candle flame	3–4	–	–	3–4
Gas flame (fish tail)	3–8	2.7	0.004	3–8
Frosted incandescent lamp	4–8	–	–	2–5
Moore carbon-dioxide tube lamp	0.6	–	–	0.3–1.75

Taken from *Data*, 1911.

TABLE 168.—Visibility of White Lights.

Range.	Candle Power. 1	Candle Power. 2
1 sea-mile = 1855 meters	0.47	0.41
2 " "	1.9	1.6
5 " "	11.8	10.

[1] Paterson and Dudding. [2] Deutsche Seewarte.

The energy falling on 1 sq. cm. at 1m. from a candle is about 4 ergs per sec. (Rayleigh, about 8 according to Ångström.)

Table 169.

EFFICIENCY OF VARIOUS ELECTRIC LIGHTS.

	Amperes.	Terminal Watts.	Lumens.	Kw-hours for 100,000 Lumen-hours.	Total cost per 100,000 Lumen-hours at 10 cts. per Kw-hour.
Regenerative d.-c., series arc	5.5	385	11,670	3.3	0.339
Regenerative d.-c., multiple arc	5.5	605	11,670	5.18	0.527
Magnetite d.-c., series arc	6.6	528	7,370	7.16	0.729
Flame arc, d.-c., inclined electrodes	10.0	550	8,640	6.37	0.837
Mercury arc, d.-c., multiple	3.5	385	4,400	15.92	0.89
Flame arc, d.-c., inclined electrodes	8.0	440	6,140	7.16	0.966
Flame arc, d.-c., vertical electrodes	8.0	440	6,140	7.16	0.966
Luminous arc, d.-c., multiple	6.6	726	7,370	9.85	0.988
Open arc, d.-c., series	9.6	480	5,025	9.55	1.079
Magnetite arc, d.-c., series	4.0	320	2,870	11.15	1.13
Flame arc, a.-c., vertical electrodes	10.0	467	5,340	8.75	1.275
Flame arc, a.-c., inclined electrodes	10.0	467	5,340	8.75	1.275
Open arc, d.-c., series	6.6	325	2,920	11.15	1.305
Tungsten series	6.6	75	626	12.0	1.384
Flame arc, a.-c., inclined electrodes	8.0	374	3,910	9.55	1.405
Inclosed arc, d.-c., series	6.6	475	3,315	14.32	1.459
Luminous arc, d.-c., multiple	4.0	440	2,870	15.32	1.547
Tungsten, multiple	0.545	60	475	12.6	1.55
Nernst, a.-c., 3-glower	1.87	414	2,160	19.2	1.88
Nernst, d.-c., 3-glower	1.87	414	2,160	19.2	1.90
Inclosed arc, a.-c., series	7.5	480	2,410	19.9	2.05
Inclosed arc, a.-c., series	6.6	425	2,020	21.3	2.193
Tantalum, d.-c., multiple	—	40	199	21.1	2.31
Tantalum, a.-c., multiple	—	40	199	21.1	2.504
Carbon, 3.1 w. p. c., multiple	—	49.6	166	29.9	3.24
Carbon, 3.5 w. p. c., series	6.6	210	626	33.6	3.47
Carbon, 3.5 w. p. c., multiple	—	56	166	33.7	3.50
Inclosed arc, d.-c., multiple	5.0	550	1,535	35.8	3.66
Inclosed arc, d.-c., multiple	3.5	385	1,030	37.4	3.84
Inclosed arc, a.-c., multiple	6.0	430	1,124	38.3	3.94
Inclosed arc, a.-c., multiple	4.0	285	688	41.4	4.265

Paper by Prof. J. M. Bryant and Mr. H. G. Hake, Engineering Experiment Station, University of Illinois.

SENSITIVENESS OF THE EYE TO RADIATION.

(Compiled from Nutting, Bulletin of the Bureau of Standards.)

Radiation is easily visible to most eyes from 0.330μ in the violet to 0.770μ in the red. At low intensities approaching threshold values (rod vision) the maximum of spectral sensibility lies in the green at about 0.510μ for 90% of all persons. At higher intensities with the establishment of cone vision the maximum shifts towards the yellow at least as far as 0.560μ.

TABLE 170. — Variation of the Sensitiveness of the Eye with the Wave-length at Low Intensities (near Threshold Values). König.

λ	.410	.430	.450	.470	.490	.510	.530	.550	.570	.590	.610
Mean sensitiveness	0.02	0.06	0.23	0.49	0.81	1.00	0.81	0.49	0.22	0.077	0.026

TABLE 171. — Variation of Sensitiveness to Radiation of Greater Intensities.

The sensibility is approximately proportional to the intensity over a wide range. The ratio of optical- to radiation-intensity increases more rapidly for the red than for the blue or green (Purkinje phenomenon).

The intensity is given for the spectrum at 0.535μ (green).

Intensity (metre-candles) = Ratio to preceding step =	.00024 -	.00225 9.38	.0360 16	.575 16	2.30 4	9.22 4	36.9 4	147.6 4	590.4 4
Wave-length, λ.	Sensitiveness.								
0.430μ	.081	.093	.127	.128	.114	.114	–		–
.450	.33	.30	.29	.31	.23	.175	.16		–
.470	.63	.59	.54	.58	.51	.29	.26	.23	
.490	.96	(.89)	(.76)	(.89)	(.83)	.50	.45	.38	.35
.505	1.00	1.00	1.00	1.00	.99	(.76)	.66	.61	.54
.520	.88	.86	.86	.94	.99	(.85)	.85	.85	.82
.535	.61	.62	.63	.72	.91	(.98)	.98	.99	.98
.555	.26	.30	.34	.41	.62	.84	.93	.97	.98
.575	.074	.102	.122	.168	(.39)	(.63)	(.76)	(.82)	(.84)
.590	.025	.034	.054	.091	.27	.49	.61	.68	.69
.605	.008	.012	.024	.056	.173	.35	(.45)	.54	.55
.625	.004	.004	.011	.027	.098	.20	.27	.35	.35
.650	.000	.000	.003	.007	.025	.060	.085	.122	.133
.670	.000	.000	.001	.002	.007	.017	.025	.030	.030
λ, maximum sensitiveness	.503	.504	.504	.508	.513	.530	.541	.543	.544

TABLE 172. — Sensibility to Small Differences in Intensity measured as a Fraction of the Whole.

λ = I_0 in m. c. =	.670 0.060	.605 0.0056	.575 0.0029	.505 0.00017	.470 0.00012	.430 0.00012	White 0.00072
I	δI : I Köoig's data, measures from one normal person only.						
1,000,000							.036
200,000		.042	–				.027
100,000	–	.024	.032			–	.019
50,000	.021	.025	.026				.017
20,000	.016	.018	.020	.019		–	.017
10,000	.016	.016	.018	.018			.018
5,000	.018	.016	.017	.016	-		.018
2,000	.016	.018	.018	.017	.018	–	.018
1,000	.017	.020	.018	.018	.017	.018	.018
500	.020	.021	.018	.019	.018	.021	.019
200	.022	.022	.022	.022	.021	.024	.022
100	.029	.028	.027	.024	.022	.025	.030
50	.038	.038	.032	.025	.025	.027	.032
10	.065	.061	.058	.036	.037	.040	.048
5	.092	.103	.089	.049	.046	.049	.059
1	.258	.212	.170	.080	.088	.074	.123
0.5	.376	.276	.21	.091	.096	.097	.188
0.10	–	–	.40	.133	.138	.137	.377
0.05			–	.183	.185	.154	.484
0.01				.271	.289	.249	–
0.005				.325	.300	.312	

The sensibility to small differences in intensity is independent of the intensity (Fechner's law). About 0.016 for moderate intensities. Greater for extreme values.

It is independent of wave-length, extremes excepted (König's law).

Sensibility to slight differences in wave-length has two pronounced maxima (one in the yellow, one in the green) and two slight maxima (extreme blue, extreme red).

The visual sensation as a function of the time approaches a constant value with the lapse of time. With blue light there seems to be a pronounced maximum at 0.07 sec., with red a slight one at 0.12 seconds, with green the sensation rises steadily to its final value. For lower intensities these max. occur later.

An intensity of 500 metre-candles is about that on a horizontal plane on a cloudy day.

TABLE 173.—The Solar Constant.

Solar constant (amount of energy falling at normal incidence on one square centimeter per minute on body at earth's mean distance) = 1.932 calories = mean 696 determinations 1902—12. Apparently subject to variations, usually within the range of 7 per cent, and occurring irregularly in periods of a week or ten days.

Computed effective temperature of the sun: from form of black-body curves, 6000° to 7000° Absolute; from λmax. = 2930 and max. = 0.470μ, 6230°; from total radiation, $J = 76.8 \times 10^{-12} \times T^4$, 5830°.

TABLE 174.—Solar spectrum energy (arbitrary units) and its transmission by the earth's atmosphere.

Values computed from $e_m = e_0 a^m$, where e_m is the intensity of solar energy after transmission through a mass of air m; m is unity when the sun is in the zenith, and approximately = sec. zenith distance for other positions (see table 180); e_0 = the energy which would have been observed had there been no absorbing atmosphere; a is the fractional amount observed when the sun is in the zenith.

Wave-length. μ	Transmission coefficients, a. Washington.	Mount Wilson.	Mount Whitney.	One mile nearer earth.	Intensity Solar Energy. Arbitrary Units. m = 0	Mount Whitney. m = 1	Mount Wilson. m = 1	2	4	6	Washington. m = 1	2	3	4	6
0.30	—	(.460)	(.550)	—	54	30	25	11	2	1	—	—	—	—	—
.32	—	.520	.615	—	111	68	58	30	8	2	—	—	—	—	—
.34	—	.580	.692	—	232	160	135	78	26	9	—	—	—	—	—
.36	—	.635	.741	—	302	224	192	122	49	20	—	—	—	—	—
.38	(.380)	.676	.784	.562	354	278	239	162	74	34	134	51	19	7	3
.40	.560	.729	.809	.768	414	335	302	220	117	62	232	130	73	41	13
.46	.690	.832	.887	.829	618	548	514	428	296	205	426	294	203	140	67
.50	.733	.862	.919	.850	606	557	522	450	334	248	441	323	237	174	94
.60	.779	.900	.940	.866	504	474	454	409	331	268	393	306	238	185	112
.70	.858	.950	.964	.903	364	351	346	329	297	268	312	268	230	197	145
.80	.886	.970	.976	.915	266	260	258	250	235	221	236	209	185	164	145
1.00	.922	.980	.975	.941	166	162	163	160	154	147	153	141	130	120	102
1.50	.938	.976*	.965	.961	63	61	61*	60*	57*	55*	59	55	52	49	43
2.00	.912	.970*	.932	.940	25	23	24*	23*	21*	19*	23	21	19	17	14

Transmission coefficients are for period when there was apparently no volcanic dust in the air.
* Possibly too high because of increased humidity towards noon.

TABLE 175.—The intensity of Solar Radiation in different sections of the spectrum, ultra-violet, visual infra-red. Calories.

Wave-length. μ to μ	Mount Whitney. m = 0	m = 1	2	3	4	Mount Wilson. m = 1	2	3	4	Washington. m = 1	2	3	4
0.00 to 0.45	.31	.25	.19	.16	.13	.23	.16	.12	.09	.13	.06	.04	.02
0.45 to 0.70	.71	.67	.62	.58	.54	.65	.57	.51	.45	.53	.40	.30	.24
0.70 to ∞	.91	.87	.85	.82	.80	.69	.68	.66	.63	.69	.62	.57	.53
0.00 to ∞	1.93	1.78	1.66	1.56	1.47	1.57	1.42	1.28	1.17	1.35	1.08	.90	.79

TABLE 176.—Distribution of brightness (Radiation) over the Solar Disk.

(These observations extend over only a small portion of a sun-spot cycle.)

Wave-length.	μ 0.323	μ 0.386	μ 0.433	μ 0.456	μ 0.481	μ 0.501	μ 0.534	μ 0.604	μ 0.670	μ 0.699	μ 0.866	μ 1.031	μ 1.225	μ 1.655	μ 2.097
Fraction Radius. 0.00	144	338	456	515	511	489	463	399	333	307	174	111	77.6	39.5	14.0
0.40	128	312	423	486	483	463	440	382	320	295	169	108	75.7	38.9	13.8
0.55	120	289	395	455	456	437	417	365	308	284	163	105.5	73.8	38.2	13.6
0.65	112	267	368	428	430	414	396	348	295	273	159	103	72.2	37.6	13.4
0.75	99	240	333	390	394	380	366	326	281	258	152	99	69.8	36.7	13.1
0.825	86	214	296	351	358	347	337	304	262	243	145	94.5	67.1	35.7	12.8
0.875	76	188	266	317	324	323	312	284	247	229	138	90.5	64.7	34.7	12.5
0.92	64	163	233	277	290	286	281	259	227	212	130	86	61.6	33.6	12.2
0.95	49	141	205	242	255	254	254	237	210	195	122	81	58.7	32.3	11.7

Taken from vols. II and III and unpublished data of the Astrophysical Observatory of the Smithsonian Institution. Schwartzchild and Villiger: Astrophysical Journal, 23, 1906.

ATMOSPHERIC TRANSPARENCY AND SOLAR RADIATION.

TABLE 177.—Transmission of Radiation Through Moist and Dry Air.

This table gives the wave-length, λ; a the transmission of radiation by dry air above Mount Wilson (altitude = 1730 m. barometer, 620 mm.) for a body in the zenith; finally a correction factor, a_w, due to such a quantity of aqueous vapor in the air that if condensed it would form a layer 1 cm. thick. Except in the bands of selective absorption due to the air, a agrees very closely with what would be expected from purely molecular scattering. a_w is very much smaller than would be correspondingly expected, due possibly to the formation of ions by the ultra-violet light from the sun. The transmission varies from day to day. However, values for clear days computed as follows agree within a per cent or two of those observed when the altitude of the place is such that the effect due to dust may be neglected, e. g. for altitudes greater than 1000 meters. If B = the barometric pressure in mm., w, the amount of precipitable water in cm., then $a_B = a^{\frac{B}{620}} a_w^w$. w is best determined spectroscopically (Astrophysical Journal, 35, p. 149, 1912, 37, p. 359, 1913) otherwise by formula derived from Hann, $w = 2.3 e_w 10^{-\frac{h}{22000}}$, e_w being the vapor pressure in cm. at the station, h, the altitude in meters.

λ (μ)	.360	.384	.413	.452	.503	.535	.574	.624	.653	.720	.986	1.74
a	(.660)	.713	.783	.840	.885	.898	.905	.929	.938	.970	.986	.990
a_w	.950	.960	.965	.967	.977	.980	.974	.978	.985	.988	.990	.990

Fowle, Astrophysical Journal, 38, 1913.

TABLE 178.—Brightness of (radiation from) Sky at Mt. Wilson (1730 m.) and Flint Island (sea level).

Zenith dist. of zone	0–15°	15–35°	35–50°	50–60°	60–70°	70–80°	80–90°	–	Sun.
10^8 × mean ratio sky/sun Mt. Wilson	1500*	400	520	610	660	700	720		–
" " Flint Island	115	122	128	150	185	210	460		–
Ditto × area of zone Mt. Wilson	51.0	58.8	91.5	87.2	104.3	117.6	125.3		636
" " " Flint Island	3.9	17.9	22.5	21.4	29.2	35.3	80.0		210
Altitude of sun			5°	15°	25°	35°	47½°	65°	82½°
Sun's brightness, cal. per cm.² per min.			.533	.900	1.233	1.358	1.413	1.496	1.521
Ditto on horizontal surface			.046	.233	.524	.780	1.041	1.355	1.507
Mean brightness on normal surface sky × 10^8/sun			423	403	.385	365	346	326	310
Total sky radiation on horizontal cal. per cm.² per m.			.056	.110	.162	.189	.205	.226	.240
Total sun + sky, ditto	–	–	.102	.343	.686	.969	1.246	1.581	1.747

* Includes allowance for bright region near sun. For the dates upon which the observation of the upper portion of table were taken, the mean ratios of total radiation sky/sun, for equal angular areas, at normal incidence, at the island and on the mountain, respectively, were 636 × 10−8 and 210 × 10−8, on a horizontal surface, 305 × 10−8 and 77 × 10−8; for the whole sky, at normal incidence, 0.57 and 0.20; on a horizontal surface 0.27 and 0.07. Annals of the Astrophysical Observatory of the Smithsonian Institution, vols. II and III, and unpublished researches (Abbot).

TABLE 179.—Relative Distribution in Normal Spectrum of Sunlight and Sky-light at Mount Wilson.

Zenith distance about 50°.

	μ	μ	μ	μ	μ	μ	C	D	b	F
Place in Spectrum	0.422	0.457	0.491	0.566	0.614	0.660				
Intensity Sunlight	186	232	227	211	191	166				
Intensity Sky-light	1194	986	701	395	231	174				
Ratio at Mt. Wilson	642	425	309	187	121	105	102	143	246	316
Ratio computed by Rayleigh	.	–	–	–	–	–	102	164	258	328
Ratio observed by Rayleigh		–	–		–	–	102	168	291	369

TABLE 180.—Air Masses.

See Table 174 for definition. Besides values derived from the pure secant formula, the table contains those derived from various other more complex formula, taking into account the curvature of the earth, refraction, etc. The most recent is that of Bemporad.

Zenith Dist.	0°	20°	40°	60°	70°	75°	80°	85°	88°
Secant	1.00	1.064	1.305	2.000	2.924	3.864	5.76	11.47	28.7
Forbes	1.00	1.065	1.306	1.995	2.902	3.809	5.57	10.22	18.9
Bouguer	1.00	1.064	1.305	1.990	2.900	3.805	5.56	10.20	19.0
Laplace	1.00	–	–	1.993	2.899	–	5.56	10.20	18.8
Bemporad	1.00	–	–	1.995	2.904	–	5.60	10.39	19.8

The Laplace and Bemporad values, Lindholm, Nova Acta R. Soc. Upsal. 3, 1913; the others, Radau's Actinometric, 1877.

RELATIVE INTENSITY OF SOLAR RADIATION.

TABLE 181. — Mean intensity J for 24 hours of solar radiation on a horizontal surface at the top of the atmosphere and the solar radiation A, in terms of the solar radiation, A_0, at earth's mean distance from the sun.

Date.	Motion of the sun in longitude.	Relative Mean Vertical Intensity $\left(\frac{J}{A_0}\right)$. Latitude north.										$\frac{A}{A_0}$.
		0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	
Jan. 1	0.99°	0.303	0.265	0.220	0.169	0.117	0.066	0.018				1.0335
Feb. 1	31.54	.312	.282	.244	.200	.150	.100	.048	0.006			1.0288
Mar. 1	59.14	.320	.303	.279	.245	.204	.158	.108	.056	0.013		1.0173
Apr. 1	89.70	.317	.319	.312	.295	.269	.235	.195	.148	.101	0.082	1.0009
May 1	119.29	.303	.318	.330	.329	.320	.302	.278	.253	.255	.259	0.9841
June 1	149.82	.287	.315	.334	.345	.349	.345	.337	.344	.360	.366	0.9714
July 1	179.39	.283	.312	.333	.347	.352	.351	.345	.356	.373	.379	0.9666
Aug. 1	209.94	.294	.316	.330	.334	.330	.318	.300	.282	.295	.300	0.9709
Sept. 1	240.50	.310	.318	.316	.305	.285	.256	.220	.180	.139	.140	0.9828
Oct. 1	270.07	.317	.308	.289	.261	.225	.183	.135	.084	.065		0.9995
Nov. 1	300.63	.312	.286	.251	.211	.164	.114	.063	.018			1.0164
Dec. 1	330.19	.304	.267	.224	.175	.124	.072	.024				1.0288
Year....		0.305	0.301	0.289	0.268	0.241	0.209	0.173	0.144	0.133	0.126	

TABLE 182. — Mean Monthly and Yearly Temperatures.

Mean temperatures of a few selected American stations, also of a station of very high, one of very low and one of very small, range of temperature.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1 Hebron-Rama (Labr.)	−20.7	−20.9	−15.6	− 6.9	+ 0.2	+ 4.5	+ 7.6	+ 8.0	+ 4.5	− 0.8	− 6.2	−16.2	− 5.2
2 Winnipeg (Canada)	−21.6	−18.8	−11.0	+ 1.9	+10.9	+17.1	+18.9	+17.6	+11.6	+ 4.1	− 7.6	−15.7	+ 0.6
3 Montreal	−10.9	− 9.1	− 4.3	+ 4.8	+12.6	+18.3	+20.5	+19.3	+14.7	+ 7.8	− 0.2	− 7.1	+ 5.5
4 Boston	− 2.8	− 2.2	+ 1.2	+ 7.3	+13.6	+19.1	+21.8	+20.6	+16.9	+11.1	+ 4.8	− 0.5	+ 9.2
5 Chicago	− 4.8	− 2.9	+ 1.2	+ 7.9	+13.4	+19.7	+22.2	+21.6	+17.9	+11.1	+ 3.6	− 1.5	+ 9.1
6 Denver	− 2.1	+ 0.1	+ 3.8	+ 8.3	+13.6	+19.1	+22.1	+21.2	+16.6	+10.3	+ 3.3	0.0	+ 9.7
7 Washington	+ 0.7	+ 2.1	+ 5.2	+11.7	+17.7	+22.9	+24.9	+23.7	+19.9	+13.4	+ 6.9	+ 2.3	+12.6
8 Pikes Peak	−16.4	−15.6	−13.4	−10.4	− 5.3	+ 0.4	+ 4.5	+ 3.6	− 0.3	− 5.8	−11.8	−14.4	− 7.1
9 St. Louis	− 0.8	+ 1.7	+ 6.2	+13.4	+18.8	+24.0	+26.0	+24.9	+20.8	+14.2	+ 6.4	+ 2.0	+13.1
10 San Francisco	+10.1	+10.9	+12.0	+12.6	+13.7	+14.7	+14.6	+14.8	+15.8	+15.2	+13.5	+10.8	+13.2
11 Yuma	+12.3	+14.9	+18.1	+21.0	+25.1	+29.4	+33.1	+32.6	+29.1	+22.8	+16.6	+13.3	+22.3
12 New Orleans	+12.1	+14.5	+16.7	+20.6	+23.7	+26.8	+27.9	+27.5	+25.7	+21.0	+15.9	+13.1	+20.4
13 Massaua	+25.6	+26.0	+27.1	+29.0	+31.1	+33.5	+34.8	+34.7	+33.3	+31.7	+29.0	+27.0	+30.3
14 Ft. Conger (Greenl'd)	−39.0	−40.1	−33.5	−25.3	−10.0	+ 0.4	+ 2.8	+ 1.0	− 9.0	−22.7	−30.9	−33.4	−20.0
15 Werchojansk	−51.0	−45.3	−32.5	−13.7	+ 2.0	+12.3	+15.5	+10.1	+ 2.5	−15.0	−37.8	−47.0	−16.7
16 Batavia	+25.3	+25.4	+25.8	+26.3	+26.4	+26.0	+25.7	+25.9	+26.3	+26.4	+26.2	+25.6	+25.9

Lat., Long., Alt. respectively: (1) +58°.5, 63°.0 W, —; (2) +49.9, 97.1 W, 233m.; (3) +45.5, 73.6 W, 57m.; (4) +42.3, 71.1 W, 38m.; (5) +41.9, 87.6 W, 251m.; (6) +39.7, 105.0 W, 1613m.; (7) +38.9, 77.0 W, 34m.; (8) +38.8, 105.0 W, 4308m.; (9) +38.6, 90.2 W, 173m.; (10) +37.8, 122.5 W, 47m.; (11) +32.7, 114.6 W, 43m.; (12) +30.0, 90.1 W, 16m.; (13) +15.6, 37.5 E, 9m.; (14) +81.7, 64.7 W., —; (15) +67.6, 133.8 E, 140m.; (16) −6.2, 106.8 E, 7m.

Taken from Hann's Lehrbuch der Meteorologie, 2'nd edition, which see for further data.

TABLE 183. — Glasses Made by Schott and Gen, Jena.

The following constants are for glasses made by Schott and Gen, Jena: n_A, n_C, n_D, n_F, n_G, are the indices of refraction in air for A=0.7682μ, C=0.6563μ, D=0.5893, F=0.4861, G′=0.4341. $v=(n_D-1)/(n_F-n_C)$. Ultra-violet indices: Simon, Wied. Ann. 53, 1894. Infra-red: Rubens, Wied. Ann. 45, 1892. Table is revised from Landolt, Börnstein and Meyerhoffer, Kayser, Handbuch der Spectroscopie, and Schott and Gen's list No. 751, 1909. See also Hovestadt's "Jena Glass."

Catalogue Type =	O 546	O 381	O 184	O 102	O 165	S 57
Designation =	Zinc-Crown.	Higher Dispersion Crown.	Light Silicate Flint.	Heavy Silicate Flint.	Heavy Silicate Flint.	Heaviest Silicate Flint.
Melting Number =	1092	1151	451	469	500	163
v =	60.7	51.8	41.1	33.7	27.6	22.2
Kind of Light and Wave-length.						
Cd 0.2763μ	1.56759		-	-	-	
Cd .2837	1.56372	-	-	-	-	-
Cd .2980	1.55723	1.57093	1.65397	-	-	-
Cd .3403	1.54369	1.55262	1.63320	1.71968	1.85487	
Cd .3610	1.53897	1.54664	1.61388	1.70536	1.83263	-
H .4340μ	1.52788	1.53312	1.59355	1.67561	1.78800	1.94493
H .4861	1.52299	1.52715	1.58515	1.66367	1.77091	1.91890
Na .5893	1.51698	1.52002	1.57524	1.64985	1.75130	1.88995
H .6563	1.51446	1.51712	1.57119	1.64440	1.74368	1.87893
K .7682	1.51143	1.51368	1.56669	1.63820	1.73530	1.86702
.800μ	1.5103	1.5131	1.5659	1.6373	1.7339	1.8650
1.200	1.5048	1.5069	1.5585	1.6277	1.7215	1.8481
1.600	1.5008	1.5024	1.5535	1.6217	1.7151	1.8396
2.000	1.4967	1.4973	1.5487	1.6171	1.7104	1.8316
2.400	-	-	1.5440	1.6131	-	1.8286

Percentage composition of the above glasses:

O 546, SiO_2, 65.4; K_2O, 15.0; Na_2O, 5.0; BaO, 9.6; ZnO, 2.0; Mn_2O_3, 0.1; As_2O_3, 0.4; B_2O_3, 2.5.
O 381, SiO_2, 68.7; PbO, 13.3; Na_2O, 15.7; ZnO, 2.0; MnO_2, 0.1; As_2O_5, 0.2.
O 184, SiO_2, 53.7; PbO, 36.0; K_2O, 8.3; Na_2O, 1.0; Mn_2O_3, 0.06; As_2O_3, 0.3.
O 102, SiO_2, 40.0; PbO, 52.6; K_2O, 6.5; Na_2O, 0.5; Mn_2O_3, 0.09; As_2O_5, 0.3.
O 165, SiO_2, 29.26; PbO, 67.5; K_2O, 3.0; Mn_2O_3, 0.04; As_2O_3, 0.2.
S 57, SiO_2, 21.9; PbO, 78.0; As_2O_5, 0.1.

TABLE 184. — Jena Glasses.

No. and Type of Jena Glass.	n_D for D	n_F-n_C	$v=\frac{n_D-1}{n_F-n_C}$	n_D-n_A	n_F-n_D	$n_{G'}-n_F$	Specific Weight.
O 225 Light phosphate crown	1.5159	.00737	70.0	.00485	.00515	.00407	2.58
O 802 Boro-silicate crown	1.4967	0765	64.9	0504	0534	0423	2.38
UV 3199 Ultra-violet crown	1.5035	0781	64.4	0514	0546	0432	2.41
O 227 Barium-silicate crown	1.5399	0909	59.4	0582	0639	0514	2.73
O 114 Soft-silicate crown	1.5151	0910	56.6	0577	0642	0521	2.55
O 608 High-dispersion crown	1.5149	0943	54.6	0595	0666	0543	2.60
UV 3248 Ultra-violet flint	1.5332	0964	55.4	0611	0680	0553	2.75
O 381 High-dispersion crown	1.5262	1026	51.3	0644	0727	0596	2.70
O 602 Baryt light flint	1.5676	1072	53.0	0675	0759	0618	3.12
S 389 Borate flint	1.5686	1102	51.6	0712	0775	0629	2.83
O 726 Extra light flint	1.5398	1142	47.3	0711	0810	0669	2.87
O 154 Ordinary light flint	1.5710	1327	43.0	0819	0943	0791	3.16
O 184 " " "	1.5900	1438	41.1	0882	1022	0861	3.28
O 748 Baryt flint	1.6235	1599	39.1	9965	1142	0965	3.67
O 102 Heavy flint	1.6489	1919	33.8	1152	1372	1180	3.87
O 41 " "	1.7174	2434	29.5	1439	1749	1521	4.49
O 165 " "	1.7541	2743	27.5	1607	1974	1730	4.78
S 386 Heavy flint	1.9170	4289	21.4	2451	3109	2808	6.01
S 57 Heaviest flint	1.9626	4882	19.7	2767	3547	3252	6.33

TABLE 185. — Change of Indices of Refraction for 1° C in Units of the Fifth Decimal Place.

No. and Designation.	Mean Temp.	C	D	F	G′	$\frac{-\Delta n}{n}100$
S 57 Heavy silicate flint	58.8°	1.204	1.447	2.090	2.810	0.0166
O 154 Light silicate flint	58.4	0.225	0.261	0.334	0.407	0.0078
O 327 Baryt flint light	58.3	—0.008	0.014	0.080	0.137	0.0079
O 225 Light phosphate crown	58.1	—0.202	—0.190	—0.168	—0.142	0.0049

Pulfrich, Wied. Ann. 45, p. 609, 1892.

TABLE 186. — Index of Refraction of Rock Salt in Air.

λ(μ).	n.	Observer.	λ(μ).	n.	Observer.	λ(μ).	n.	Observer.
0.185409	1.89348	M	0.88396	1.534011	L	5.8932	1.516014	P
.204470	1.76964	"	.972298	1.532532	"	"	1.515553	L
.291368	1.61325	"	.98220	1.532435	P	6.4825	1.513628	P
.358702	1.57932	"	1.036758	1.531762	L	"	1.513467	L
.441587	1.55962	"	1.1786	1.530372	P	7.0718	1.511062	P
.486149	1.55338	"	"	1.530374	L	7.6611	1.508318	"
"	1.553406	L	1.555137	1.528211	"	7.9558	1.506804	"
"	1.553399	P	1.7680	1.527440	P	8.8398	1.502035	"
.58902	1.544340	L	"	1.527441	L	10.0184	1.494722	"
.58932	1.544313	P	2.073516	1.526554	"	11.7864	1.481816	"
.656304	1.540672	P	2.35728	1.525863	P	12.9650	1.471720	"
"	1.540702	L	"	1.525849	L	14.1436	1.460547	"
.706548	1.538633	P	2.9466	1.524534	P	14.7330	1.454404	"
.766529	1.536712	P	3.5359	1.523173	"	15.3223	1.447494	"
.76824	1.53666	M	4.1252	1.521648	P	15.9116	1.441032	"
.78576	1.536138	P	"	1.521625	L	20.57	1.3735	RN
.88396	1.534011	P	5.0092	1.518978	P	22.3	1.340	"

$$n^2=a^2+\frac{M_1}{\lambda^2-\lambda_1^2}+\frac{M_2}{\lambda^2-\lambda_2^2}-k\lambda^2-h\lambda^4 \text{ or } =b^2+\frac{M_1}{\lambda^2-\lambda_1^2}+\frac{M_2}{\lambda^2-\lambda_2^2}-\frac{M_3}{\lambda_3^2-\lambda^2}$$

where $a^2=2.330165$, $M_1=0.01278685$, $\lambda_1^2=0.0148500$, $M_2=0.005343924$; $\lambda_2^2=0.02547414$, $k=0.0009285837$, $h=0.000000286086$; $b^2=5.680137$, $M_3=12059.95$, $\lambda_3^2=3600.$ (P)

TABLE 187. — Change of Index of Refraction for 1° C in Units of the 5th Decimal Place.

0.202μ	+3.134	Mi	0.441μ	−3.425	Mi	C line	−3.749	Pl	0.760μ	−3.73	L
.210	+1.570	"	.508	−3.517	"	D "	−3.739	"	1.368	−3.88	L
.224	−0.187	"	.643	−3.636	"	F "	−3.648	"	1.88	−3.85	L
.298	−2.727	"				G′ "	−3.585	"	4.3	−3.82	L

L Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. I, 1900.
M Martens, Ann. d. Phys. 6, 1901, 8, 1902.
Mi Micheli, Ann. d. Phys. 7, 1902.
P Paschen, Wied. Ann. 26, 1908.
Pl Pulfrich, Wied. Ann. 45, 1892.
RN Rubens and Nichols, Wied. Ann. 60, 1897.

TABLE 188. — Index of Refraction of Silvine (Potassium Chloride) in Air.

λ(μ).	n	Observer.	λ(μ).	n.	Observer.	λ(μ).	n.	Observer.
0.185409	1.82710	M	1.1786	1.478311	P	8.2505	1.462726	P
.200090	1.71870	"	"	1.47824	W	"	1.46276	W
.21946	1.64745	"	1.7680	1.475890	P	8.8398	1.460858	P
.257317	1.58125	"	"	1.47589	W	"	1.46092	W
.281640	1.55836	"	2.35728	1.474751	P	10.0184	1.45672	P
.308227	1.54136	"	2.9466	1.473834	"	"	1.45673	W
.358702	1.52115	"	"	1.47394	W	11.786	1.44919	P
.394415	1.51219	"	3.5359	1.473049	P	"	1.44941	W
.467832	1.50044	"	"	1.47304	W	12.965	1.44346	P
.508606	1.49620	"	4.7146	1.471122	P	"	1.44385	W
.58933	1.49044	P	"	1.47129	W	14.144	1.43722	P
.67082	1.48669	M	5.3039	1.470013	P	15.912	1.42617	"
.78576	1.483282	P	"	1.47001	W	17.680	1.41403	"
.88398	1.481422	P	5.8932	1.468804	P	20.60	1.3882	RN
.98220	1.480084	"	"	1.46880	W	22.5	1.369	"

$$n^2=a^2+\frac{M_1}{\lambda^2-\lambda_1^2}+\frac{M_2}{\lambda^2-\lambda_2^2}-k\lambda^2-h\lambda^4 \text{ or } =b^2+\frac{M_1}{\lambda^2-\lambda_1^2}+\frac{M_2}{\lambda^2-\lambda_2^2}+\frac{M_3}{\lambda_3^2-\lambda^2}$$

$a^2=2.174967$, $M_1=0.008344206$, $\lambda_1^2=0.0119082$, $M_2=0.00698382$; $\lambda_2^2=0.0255550$, $k=0.000513495$, $h=0.0000000167587$; $b^2=3.866619$, $M_3=5569.715$, $\lambda_3^2=3292.47$ (P)

W Weller, see Paschen's article. Other references as under Table 187, above.

INDEX OF REFRACTION.

TABLE 189. — Index of Refraction of Fluorite in Air.

λ (μ)	n	Observer	λ (μ)	n	Observer	λ (μ)	n	Observer.
0.1856	1.50940	S	1.4733	1.42641	P	4.1252	1.40855	P
.19881	1.49629	"	1.5715	1.42596	"	4.4199	1.40559	"
.21441	1.48462	"	1.6206	1.42582	"	4.7146	1.40238	"
.22645	1.47762	"	1.7680	1.42507	"	5.0092	1.39898	"
.25713	1.46476	"	1.9153	1.42437	"	5.3036	1.39529	"
.32525	1.44987	"	1.9644	1.42413	"	5.5985	1.39142	"
.34555	1.44697	"	2.0626	1.42359	"	5.8932	1.38719	"
.39681	1.44214	"	2.1608	1.42308	"	6.4825	1.37819	"
.48607	1.43713	P	2.2100	1.42288	"	7.0718	1.36805	"
.58930	1.43393	P	2.3573	1.42199	"	7.6612	1 35680	"
.65618	1.43257	S	2.5537	1.42088	"	8.2505	1.34444	"
.68671	1.43200	"	2.6519	1.42016	"	8.8398	1.33079	"
.71836	1.43157	"	2.7502	1.41971	"	9.4291	1.31612	"
.76040	1.43101	"	2.9466	1.41826	"	51.2	3.47	RA
.8840	1.42982	P	3.1430	1.41707	"	61.1	2.66	"
1.1786	1.42787	"	3.2413	1.41612	"	∞	2.63	S
1.3756	1.42690	"	3.5359	1.41379	"			
1.4733	1.42641	"	3.8306	1.41120	"	References under Table 173.		

$$n^2 = a^2 + \frac{M_1}{\lambda^2 - \lambda_1^2} - e\lambda^2 - f\lambda^4 \text{ or } = b^2 + \frac{M_2}{\lambda^2 - \lambda_v^2} + \frac{M_3}{\lambda^2 - \lambda_r^2}$$

where $a^2 = 2.03882$, $M_1 = 0.0062183$, $\lambda_1^2 = 0.007706$, $e = 0.0031999$;
$f = 0.000002916$, $b^2 = 6.09651$, $M_2 = 0.0061386$, $\lambda_v^2 = 0.00884$;
$M_3 = 5114.65$, $\lambda_r^2 = 1260.56$, $\lambda_v = 0.0940\mu$, $\lambda_r = 35.5\mu$ (P)

TABLE 190. — Change of Index of Refraction for 1° C in Units of the 5th Decimal Place.

C line, —1.220; D, —1.206; F, —1.170; G, —1.142. (Pl)

TABLE 191. — Index of Refraction of Iceland Spar ($CaCO_3$) in Air.

λ (μ)	n_o	n_e	Obser-ver.	λ (μ)	n_o	n_e	Obser-ver.	λ (μ)	n_o	n_e	Obser-ver.
0.198	–	1.5780	M	0.508	1.6653	1.4896	M	0.991	1.6438	1.4802	C
.200	1.9028	1.5765	"	.533	1.6628	1.4884	"	1.229	1.6393	1.4787	"
.208	1.8673	1.5664	"	.589	1.6584	1.4864	"	1.307	1.6379	1.4783	"
.226	1.8130	1.5492	–	.643	1.6550	1.4849	"	1.497	1.6346	1.4774	"
.298	1.7230	1.5151	C	.656	1.6544	1.4846	"	1.682	1.6313	–	"
.340	1.7008	1.5056	M	.670	1.6537	1.4843	"	1.749	–	1.4764	"
.361	1.6932	1.5022	C	.760	1.6500	1.4826	–	1.849	1.6280	–	"
.410	1.6802	1.4964	–	.768	1.6497	1.4826	M	1.908	–	1.4757	"
.434	1.6755	1.4943	M	.801	1.6487	1.4822	C	2.172	1.6210	–	"
.486	1.6678	1.4907	"	.905	1.6458	1.4810	"	2.324	–	1.4739	"

C Carvallo, J. de Phys. (3), 9, 1900.
M Martens, Ann. der Phys. (4) 6, 1901, 8, 1902.
P Paschen, Wied. Ann. 56, 1895.
Pl Pulfrich, Wied. Ann 45, 1892.
RA Rubens-Aschkinass, Wied. Ann. 67, 1899.
S Starke, Wied. Ann. 60, 1897.

TABLE 192. — Index of Refraction of Nitroso-dimethyl-aniline. (Wood.)

λ	n	λ	n	λ	n	λ	n	λ	n
0.497	2.140	0.525	1.945	0.584	1.815	0.636	1.647	0.713	1.718
.500	2.114	.536	1.909	.602	1.796	.647	1.758	.730	1.713
.506	2.074	.546	1.879	.611	1.783	.659	1.750	.749	1.709
.508	2.025	.557	1.857	.620	1.778	.669	1.743	.763	1.697
.516	1.985	.569	1.834	.627	1.769	.696	1.723		

Nitroso-dimethyl-aniline has enormous dispersion in yellow and green, metallic absorption in violet. See Wood, Phil. Mag 1903.

INDEX OF REFRACTION.

TABLE 193. — Index of Refraction of Quartz (SiO_2).

Wave-length.	Index Ordinary Ray.	Index Extraordinary Ray.	Temperature ° C.	Wave-length.	Index Ordinary Ray.	Index Extraordinary Ray.	Temperature ° C.
0.185	1.67582	1.68999	18	0.656	1.54189	1.55091	18
.193	.65997	.67343	"	.686	.54099	.54998	"
.198	.65090	.66397	"	.760	.53917	.54811	"
.206	.64038	.65300	"	1.160	.5329		–
.214	.63041	.64264	"	.969	.5216		–
.219	.62494	.63698	"	2.327	.5156		–
.231	.61399	.62560	"	.84	.5039		–
.257	.59622	.60712	"	3.18	.4944		–
.274	.58752	.59811	"	.63	.4799	Rubens.	–
.340	.56748	.57738	"	.96	.4679		–
.396	.55815	.56771	"	4.20	.4569		–
.410	.55650	.56600	"	5.0	.417		–
.486	.54968	.55896	"	6.45	.274		–
0.598	1.54424	1.55334	"	7.0	1.167		–

Except Rubens' values, — means from various authorities.

TABLE 194. — Indices of Refraction for various Alums.*

R	Density.	Temp. C.°	Index of refraction for the Fraunhofer lines.							
			a	B	C	D	E	b	F	G
Aluminium Alums. $R\mathrm{Al}(SO_4)_2+12H_2O$.†										
Na	1.667	17–28	1.43492	1.43563	1.43653	1.43884	1.44185	1.44231	1.44412	1.44804
$NH_3(CH_3)$	1.568	7–17	.45013	.45062	.45177	.45410	.45691	.45749	.45941	.46363
K	1.735	14–15	.45226	.45303	.45398	.45645	.45934	.45996	.46181	.46609
Rb	1.852	7–21	.45232	.45328	.45417	.45660	.45955	.45999	.46192	.46618
Cs	1.961	15–25	.45437	.45517	.45618	.45856	.46141	.46203	.46386	.46821
NH_4	1.631	15–20	.45509	.45599	.45693	.45939	.46234	.46288	.46481	.46923
Tl	2.329	10–23	.49226	.49317	.49443	.49748	.50128	.50209	.50463	.51076
Chrome Alums. $R\mathrm{Cr}(SO_4)_2+12H_2O$.†										
Cs	2.043	6–12	1.47627	1.47732	1.47836	1.48100	1.48434	1.48491	1.48723	1.49280
K	1.817	6–17	.47642	.47738	.47865	.48137	.48459	.48513	.48753	.49309
Rb	1.946	12–17	.47660	.47756	.47868	.48151	.48486	.48522	.48775	.49323
NH_4	1.719	7–18	.47911	.48014	.48125	.48418	.48744	.48794	.49040	.49594
Tl	2.386	9–25	.51692	.51798	.51923	.52280	.52704	.52787	.53082	.53808
Iron Alums. $R\mathrm{Fe}(SO_4)_2+12H_2O$.†										
K	1.806	7–11	1.47639	1.47706	1.47837	1.48169	1.48580	1.48670	1.48939	1.49605
Rb	1.916	7–20	.47700	.47770	.47894	.48234	.48654	.48712	.49003	.49700
Cs	2.061	20–24	.47825	.47921	.48042	.48378	.48797	.48867	.49136	.49838
NH_4	1.713	7–20	.47927	.48029	.48150	.48482	.48921	.48993	.49286	.49980
Tl	2.385	15–17	.51674	.51790	.51943	.52365	.52859	.52946	.53284	.54112

* According to the experiments of Soret (Arch. d. Sc. Phys. Nat. Genève, 1884, 1888, and Comptes Rendus, 1885).
† *R* stands for the different bases given in the first column.
For other alums see reference on Landolt-Börnstein-Roth Tabellen.

Table 195.

INDEX OF REFRACTION.

Various Monorefringent or Optically Isotropic Solids.

Substance.	Line of Spectrum.	Index of Refraction.	Authority.
Agate (light color)	red	1.5374	De Senarmont.
Albite glass	D	1.4890	Larsen, 1909.
Ammonium chloride	D	1.6422	Grailich.
Anorthite glass	D	1.5755	Larsen, 1909.
Arsenite	D	1.755	DesCloiseaux.
Barium nitrate	D	1.5716	Fock.
Bell metal	D	1.0052	Beer.
Blende	Li	2.34165	Ramsay.
Blende	Na	2.36923	Ramsay.
Blende	Tl	2.40069	Ramsay.
Boric acid	C	1.46245	Bedson and Carleton Williams.
Boric acid	D	1.46303	Bedson and Carleton Williams.
Boric acid	F	1.47024	Bedson and Carleton Williams.
Borax (vitrified)	C	1.51222	Bedson and Carleton Williams.
Borax (vitrified)	D	1.51484	Bedson and Carleton Williams.
Borax (vitrified)	F	1.52068	Bedson and Carleton Williams.
Camphor	D	1.532	Kohlrausch.
Camphor	D	1.5462	Mulheims.
Diamond (colorless)	red	2.414	DesCloiseaux.
Diamond (colorless)	green	2.428	DesCloiseaux.
Diamond (brown)	B	2.46062	Schrauf.
Diamond (brown)	D	2.46986	Schrauf.
Diamond (brown)	E	2.47902	Schrauf.
Ebonite	D	1.6	Ayrton & Perry.
Fuchsin	A	2.03	Means.
Fuchsin	B	2.19	Means.
Fuchsin	C	2.33	Means.
Fuchsin	G	1.97	Means.
Fuchsin	H	1.32	Means.
Garnet (different varieties)	D	1.74 to 1.90	Various.
Gum arabic	red	1.480	Jamin.
" "	"	1.514	Wollaston.
Lime CaO	D	1.832	Wright, 1909.
Magnesium oxide	D	1.734	Wright, 1909.
Obsidian	D	1.482 to 1.496	Various.
Opal	D	1.406 1.450	"
Pitch	red	1.531	Wollaston.
Potassium bromide	D	1.5593	Topsöe and Christiansen.
" chlorstannate	"	1.6574	Topsöe and Christiansen.
" iodide	"	1.6666	Topsöe and Christiansen.
Phosphorus	"	2.1442	Gladstone & Dale.
Resins: Aloes	red	1.619	Jamin.
Canada balsam	"	1.528	Wollaston.
Colophony	"	1.548	Jamin.
Copal	"	1.528	"
Mastic	"	1.535	Wollaston.
Peru balsam	D	1.593	Baden Powell.
Selenium, vitreous	A	2.612	Wood.
Selenium, vitreous	B	2.680	Wood.
Selenium, vitreous	C	2.729	Wood.
Selenium, vitreous	D	2.93	Wood.
Silver bromide	D	2.253	Wernicke.
Silver chloride	"	2.061	Wernicke.
Silver iodide	"	2.182	Wernicke.
Sodium chlorate	"	1.5150	Dussaud.
Spinel	"	1.7155	DesCloiseaux.
Strontium nitrate	"	1.5667	Fock.

INDEX OF REFRACTION.

Uniaxial Crystals.

Substance.	Line of spectrum.	Index of refraction. Ordinary ray.	Index of refraction. Extraordinary ray.	Authority.
Alunite (alum stone)	D	1.573	1.592	Levy & Lacroix.
Ammonium arseniate	red	1.577	1.524	De Senarmont.
Anatase	D	2.5354	2.4959	Schrauf.
Apatite	D	1.6390	1.6345	"
Benzil	D	1.6588	1.6784	DesCloiseaux.
Beryl	D	1.589 to 1.570	1.582 to 1.566	Various.
Brucite	D	1.560	1.581	Kohlrausch.
Calomel	D	1.9732	2.6559	Dufet.
Cinnabar	red	2.854	3.199	DesCloiseaux
Corundum (ruby, sapphire, etc.)	red	1.767 to 1.769	1.759 1.762	"
Dioptase	green	1.667	1.723	"
Dolomite	D	1.667 to 1.696	1.506 to 1.512	Various.
Emerald (pure)	green	1.584	1.578	DesCloiseaux.
Gehlenite	D	1.666	1.661	Wright, 1908.
Greenockite	D	2.506	2.529	Merwin, 1912.
Ice at — 8° C.	D	1.309	1.313	Meyer.
Idocrase	D	1.719 to 1.722	1.717 to 1.720	DesCloiseaux.
Ivory	D	1.539	1.541	Kohlrausch.
Magnesite	D	1.717	1.515	Mallard.
Nephelite	D	1.541	1.537	Bowen, 1912.
Potassium arseniate	red	1.564	1.515	DesCloiseaux.
" "	red	1.493	1.501	De Senarmont.
Rutil	D	2.6158	2.9029	Bärwald.
Silver (red ore)	red	3.084	2.881	Fizeau.
Sodium arseniate	D	1.459	1.467	Baker.
" nitrate	D	1.587	1.336	Schrauf.
" phosphate	D	1.446	2.452	Dufet.
Strychnine sulphate	D	1.614	1.519	Martin.
Tin stone	D	1.997	2.093	Grubenman.
Tourmaline (colorless)	D	1.637	1.619	Heusser.
" (different colors)	D	1.633 to 1.650	1.616 to 1.625	Jeroféjew.
Wurtzite	D	2.356	2.378	Merwin, 1912.
Zircon (hyacinth)	red	1.92	1.97	De Senarmont.
" "	D	1.924	1.968	Sanger.

BIAXIAL CRYSTALS.

Substance.	Line of spectrum.	Index of Refraction. Minimum.	Intermediate.	Maximum.	Authority.
Amphibole	D	1.633	1.642	1.657	Lévy-Lacroix.
Andalusite	red	1.632	1.638	1.643	Lévy-Lacroix.
Anemousite	D	1.5549	1.5587	1.5634	Wright 1910.
Anglesite	D	1.8771	1.8823	1.8936	Arzruni.
Anhydrite	D	1.5693	1.5752	1.6130	Mülheims.
Anorthite	D	1.576	1.583	1.589	Bowen 1912
Antipyrin	D	1.5697	1.6935	1.7324	Liweh.
Aragonite	D	1.5301	1.6816	1.6859	Rudberg.
Axinite	red	1.6720	1.6779	1.6810	DesCloiseaux.
Barite	D	1.636	1.637	1.648	Various.
Borax	D	1.4467	1.4694	1.4724	Dufet.
Carnegeite	D	1.509	——	1.514	Bowen 1912.
Copper sulphate	D	1.5140	1.5368	1.5433	Kohlrausch.
Gypsum	D	1.5208	1.5228	1.5298	Mülheims.
Hillebrandite	D	1.605	——	1.612	Wright 1908.
Magnesium Carbonate	D	1.495	1.501	1.526	Genth, Penfield.
Magnesium Sulphate	D	1.432	1.455	1.460	Means.
Mica (muscovite)	D	1.5601	1.5936	1.5977	Pulfrich.
Olivine	D	1.661	1.678	1.697	DesCloiseaux.
Orthoclase	D	1.5190	1.5237	1.5260	"
Potassium bichromate	D	1.7202	1.7380	1.8197	Dufet.
" nitrate	D	1.3346	1.5056	1.5064	Schrauf.
" sulphate	D	1.4932	1.4946	1.4980	Topsöe & Christiansen.
Spurrite	D	1.640	1.674	1.679	Wright 1908.
Sugar (Cane)	D	1.5397	1.5667	1.5716	Calderon
Sulphur (rhombic)	D	1.9505	2.0383	2.2405	Schrauf.
Topaz (Brazilian)	D	1.6294	1.6308	1.6375	Mülheims.
Topaz (different kinds)	D	1.638 to 1.613	1.631 to 1.616	1.637 to 1.623	Various.
Wallastonite	D	1.620	1.632	1.634	Means.
Zinc sulphate	D	1.4568	1.4801	1.4836	Topsöe & Christiansen.

Table 198.

INDEX OF REFRACTION.

Indices of Refraction relative to Air for Solutions of Salts and Acids.

Substance.	Density.	Temp. C.	Indices of refraction for spectrum lines. C	D	F	H_γ	H	Authority.
(a) Solutions in Water.								
Ammonium chloride	1.067	27°.05	1.37703	1.37936	1.38473	–	1.39336	Willigen.
" "	.025	29.75	.34850	.35050	.35515	–	.36243	"
Calcium chloride .	.398	25.65	.44000	.44279	.44938	–	.46001	"
" "	.215	22.9	.39411	.39652	.40206	–	.41078	"
" "	.143	25.8	.37152	.37369	.37876	–	.38666	"
Hydrochloric acid .	1.166	20.75	1.40817	1.41109	1.41774	–	1.42816	"
Nitric acid	.359	18.75	.39893	.40181	.40857		.41961	"
Potash (caustic) . .	.416	11.0	.40052	.40281	.40808	–	.41637	Fraunhofer.
Potassium chloride .	normal	solution	.34087	.34278	.34719	1.35049	–	Bender.
" "	double	normal	.34982	.35179	.35645	.35994	–	"
" "	triple	normal	.35831	.36029	.36512	.36890	–	"
Soda (caustic) . .	1.376	21.6	1.41071	1.41334	1.41936	–	1.42872	Willigen.
Sodium chloride . .	.189	18.07	.37562	.37789	.38322	1.38746	–	Schutt.
" "	.109	18.07	.35751	.35959	.36442	.36823	–	"
" "	.035	18.07	.34000	.34191	.34628	.34969	–	"
Sodium nitrate . .	1.358	22.8	1.38283	1.38535	1.39134	–	1.40121	Willigen.
Sulphuric acid . .	.811	18.3	.43444	.43669	.44168	–	.44883	"
" "	.632	18.3	.42227	.42466	.42967	–	.43694	"
" "	.221	18.3	.36793	.37009	.37468	–	.38158	"
" "	.028	18.3	.33663	.33862	.34285	–	.34938	"
Zinc chloride . . .	1.359	26.6	1.39977	1.40222	1.40797		1.41738	"
" " . . .	.209	26.4	.37292	.37515	.38026	–	.38845	"
(b) Solutions in Ethyl Alcohol.								
Ethyl alcohol . . .	0.789	25.5	1.35791	1.35971	1.36395		1.37094	Willigen.
" "	.932	27.6	.35372	.35556	.35986	–	.36662	"
Fuchsin (nearly saturated)	–	16.0	.3918	.398	.361	–	.3759	Kundt.
Cyanin (saturated) .	–	16.0	.3831	–	.3705	–	.3821	"

Note. — Cyanin in chloroform also acts anomalously; for example, Sieben gives for a 4.5 per cent. solution $\mu_A = 1.4593$, $\mu_B = 1.4695$, μ_F(green) $= 1.4514$, μ_G (blue) $= 1.4554$. For a 9.9 per cent. solution he gives $\mu_A = 1.4902$, μ_F(green) $= 1.4497$, μ_G(blue) $= 1.4597$.

(c) Solutions of Potassium Permanganate in Water.*

Wave-length in cms. × 10⁶.	Spectrum line.	Index for 1 % sol.	Index for 2 % sol.	Index for 3 % sol.	Index for 4 % sol.	Wave-length in cms. × 10⁶.	Spectrum line.	Index for 1 % sol.	Index for 2 % sol.	Index for 3 % sol.	Index for 4 % sol.
68.7	B	1.3328	1.3342	–	1.3382	51.6	–	1.3368	1.3385	–	–
65.6	C	.3335	.3348	1.3365	.3391	50.0	–	.3374	.3383	1.3386	1.3404
61.7	–	.3343	.3365	.3381	.3410	48.6	F	.3377	–	–	.3408
59.4	–	.3354	.3373	.3393	.3426	48.0		.3381	.3395	.3398	.3413
58.9	D	.3353	.3372	–	.3426	46.4	–	.3397	.3402	.3414	.3423
56.8	–	.3362	.3387	.3412	.3445	44.7	–	.3407	.3421	.3426	.3439
55.3	–	.3366	.3395	.3417	.3438	43.4	–	.3417	–	–	.3452
52.7	E	.3363	–	–	–	42.3	–	.3431	.3442	.3457	.3468
52.2	–	.3362	.3377	.3388	–	–	–	–	–	–	–

* According to Christiansen.

INDEX OF REFRACTION.

Indices of Refraction of Liquids relative to Air.

Substance.	Temp. C.	Index of refraction for spectrum lines.					Authority.
		C	D	F	H_γ	H	
Acetone	10°	1.3626	1.3646	1.3694	1.3732	–	Korten.
Almond oil . . .	0	.4755	.4782	.4847	–	–	Olds.
Analin *	20	.5993	.5863	.6041	.6204	–	Weegmann.
Aniseed oil . . .	21.4	.5410	.5475	.5647	–	–	Willigen.
" " . . .	15.1	.5508	.5572	.5743	–	1.6084	Baden Powell.
Benzene †	10	1.4983	1.5029	1.5148	–	1.5355	Gladstone.
"	21.5	.4934	.4979	.5095	–	.5304	"
Bitter almond oil .	20	.5391	–	.5623	.5775	–	Landolt.
Bromnaphtalin . .	20	.6495	.6582	.6819	.7041	.7289	Walter.
Carbon disulphide ‡	0	1.6336	1.6433	1.6688	1.6920	1.7175	Ketteler.
" "	20	.6182	.6276	.6523	.6748	.6994	"
" "	10	.6250	.6344	.6592	–	.7078	Gladstone.
" "	19	.6189	.6284	.6352		.7010	Dufet.
Cassia oil	10	.6007	.6104	.6389		.7039	Baden Powell.
" "	22.5	.5930	.6026	.6314		.6985	" "
Chinolin	20	1.6094	1.6171	1.6361	1.6497	–	Gladstone.
Chloroform . . .	10	.4466	.4490	.4555	–	.4661	Gladstone & Dale.
" . . .	30	–	.4397	–		.4561	" "
" . . .	20	.4437	.4462	.4525		–	Lorenz.
Cinnamon oil . .	23.5	.6077	.6188	.6508	–		Willigen.
Ether	15	1.3554	1.3566	1.3606	–	1.3683	Gladstone & Dale.
"	15	.3573	.3594	.3641	–	.3713	Kundt.
Ethyl alcohol . .	0	.3677	.3695	.3739	.3773	–	Korten.
" " . .	10	.3636	.3654	.3698	.3732	–	"
" " . .	20	.3596	.3614	.3657	.3690	–	"
" " . .	15	.3621	.3638	.3683	–	.3751	Gladstone & Dale.
Glycerine	20	1.4706		1.4784	1.4828	–	Landolt.
Methyl alcohol . .	15	.3308	1.3326	.3362	–	.3421	Baden Powell.
Olive oil	0	.4738	.4763	.4825	–	–	Olds.
Rock oil	0	.4345	.4573	.4644	–	–	"
Turpentine oil . .	10.6	1.4715	1.4744	1.4817	–	1.4939	Fraunhofer.
" " . .	20.7	.4692	.4721	.4793	–	.4913	Willigen.
Toluene	20	.4911	.4955	.5070	.5170	–	Bruhl.
Water §	20	.3312	.3330	.3372	.3404	.3435	Means.

* Weegmann gives $\mu_D = 1.59668 - .000518\,t$. Knops gives $\mu_F = 1.61500 - .00056\,t$.

† Weegmann gives $\mu_D = 1.51474 - .000665\,t$. Knops gives $\mu_D = 1.51399 - .000644\,t$.

‡ Wüllner gives $\mu_C = 1.63407 - .00078\,t$; $\mu_F = 1.66908 - .00082\,t$; $\mu_h = 1.69215 - .00085\,t$.

§ Dufet gives $\mu_D = 1.33397 - 10^{-7}(125\,t + 20.6\,t^2 - .000435\,t^3 - .00115\,t^4)$ between 0° and 50°; and nearly the same variation with temperature was found by Ruhlmann, namely, $\mu_D = 1.33373 - 10^{-7}(20.14\,t^2 + .000494\,t^4)$.

Table 200.

INDEX OF REFRACTION.

Indices of Refraction of Gases and Vapors.

A formula was given by Biot and Arago expressing the dependence of the index of refraction of a gas on pressure and temperature. More recent experiments confirm their conclusions. The formula is $n_t - 1 = \frac{n_0 - 1}{1 + at} \cdot \frac{p}{760}$, where n_t is the index of refraction for temperature t, n_0 for temperature zero, a the coefficient of expansion of the gas with temperature, and p the pressure of the gas in millimeters of mercury.

(a) Indices of refraction.

Spectrum line.	10^3 (n−1) Air.	Spectrum line.	10^3 (n−1) Air.	Wave-length.	(n−1) 10^3. Air.	O.	N.	H.
				μ				
A	.2905	M	.2993	.4861	.2951	.2734	.3012	.1406
B	.2911	N	.3003	.5461	.2936	.2717	.2998	.1397
C	.2914	O	.3015	.5790	.2930	.2710	—	.1393
D	.2922	P	3023	.6563	.2919	.2698	.2982	.1387
E	.2933	Q	.3031	.4360	.2971	.2743	CO_2	.1418
F	.2943	R	.3043	.5462	.2937	.2704	.4506	.1397
G	.2962	S	.3053	.6709	.2918	.2683	.4471	.1385
H	.2978	T	.3064	6.709	.2881	.2643	.4804	.1361
K	.2980	U	.3075	8.678	.2888	.2650	.4579	.1361
L	.2987							

First 4, Cuthbertsons; the rest, Koch, 1909.

(b) The following are compiled mostly from a table published by Brühl (Zeits. für Phys. Chem. vol. 7, pp. 25–27). The numbers are from the results of experiments by Biot and Arago, Dulong, Jamin, Ketteler, Lorenz, Mascart, Chappius, Rayleigh, and Rivière and Prytz. When the number given rests on the authority of one observer the name of that observer is given. The values are for 0° Centigrade and 760 mm. pressure.

Substance.	Kind of light.	Indices of refraction and authority.	Substance.	Kind of light.	Indices of refraction and authority.
Acetone	D	1.001079–1.001100	Hydrogen	white	1.000138–1.000143
Ammonia	white	1.000381–1.000385	"	D	1.000132 Burton.
"	D	1.000373–1.000379	Hydrogen sulphide	D	1.000644 Dulong.
Argon	D	1.000281 Rayleigh.	"	D	1.000623 Mascart.
Benzol	D	1.001700–1.001823	Methane	white	1.000443 Dulong.
Bromine	D	1.001132 Mascart.	"	D	1.000444 Mascart.
Carbon dioxide	white	1.000449–1.000450	Methyl alcohol	D	1.000549–1.000623
" "	D	1.000448–1.000454	Methyl ether	D	1.000891 Mascart.
Carbon disulphide	white	1.001500 Dulong.	Nitric oxide	white	1.000303 Dulong.
"	D	1.001478–1.001485	" "	D	1.000297 Mascart.
Carbon monoxide	white	1.000340 Dulong.	Nitrogen	white	1.000295–1.000300
"	white	1.000335 Mascart.	"	D	1.000296–1.000298
Chlorine	white	1.000772 Dulong.	Nitrous oxide	white	1.000503–1.000507
"	D	1.000773 Mascart.	" "	D	1.000516 Mascart.
Chloroform	D	1.001436–1.001464	Oxygen	white	1.000272–1.000280
Cyanogen	white	1.000834 Dulong.	"	D	1.000271–1.000272
"	D	1.000784–1.000825	Pentane	D	1.001711 Mascart.
Ethyl alcohol	D	1.000871–1.000885	Sulphur dioxide	white	1.000665 Dulong.
Ethyl ether	D	1.001521–1.001544	" "	D	1.000686 Ketteler.
Helium	D	1.000036 Ramsay.	Water	white	1.000261 Jamin.
Hydrochloric acid	white	1.000449 Mascart.	"	D	1.000249–1.000259
"	D	1.000447 "			

MEDIA FOR DETERMINATIONS OF REFRACTIVE INDICES WITH THE MICROSCOPE.

TABLE 201. — Liquids, n_D (0.589μ) = 1.74 to 1.87.

In 100 parts of methylene iodide at 20° C. the number of parts of the various substances indicated in the following table can be dissolved, forming saturated solutions having the permanent refractive indices specified. When ready for use the liquids can be mixed by means of a dropper to give intermediate refractions. Commercial iodoform (CHI_3) powder is not suitable, but crystals from a solution of the powder in ether may be used, or the crystalized product may be bought. A fragment of tin in the liquids containing the SnI_4 will prevent discoloration.

CHI_3.	SnI_4.	AsI_3.	SbI_3.	S.	n_{na} at 20°.
			12		1.764
	25				1.783
	25		12		1.806
	30			6	1.820
	27	13	7		1.826
40	27	16			1.842
	31	14	8	10	1.853
35	31	16	8	10	1.868

TABLE 202. — Resin-like Substances, n_D (0.589μ) = 1.68 to 2.10.

Piperine, one of the least expensive of the alkaloids, can be obtained very pure in straw-colored crystals. When melted it dissolves the tri-iodides of arsenic and antimony very freely. The solutions are fluid at slightly above 100° and when cold, resin-like. A solution containing 3 parts antimony iodide to one part of arsenic iodide with varying proportions of piperine is easier to manipulate than one containing either iodide alone. The following table gives the necessary data concerning the composition and refractive indices for sodium light. In preparing, the constituents, in powder of about 1 mm. grain, should be weighed out and then fused *over*, not *in*, a low flame. Three-inch test tubes are suitable.

Per cent Iodides.	00.	10.	20.	30.	40.	50.	60.	70.	80.
Index of refraction	1.683	1.700	1.725	1.756	1.794	1.840	1.897	1.968	2.050

TABLE 203. — Permanent Standard Resinous Media, n_D (0.589μ) = 1.548 to 1.682.

Any proportions of piperine and rosin form a homogeneous fusion which cools to a transparent resinous mass. The following table shows the refractive indices of various mixtures. On account of the strong dispersion of piperine the refractive indices of minerals apparently matched with those of mixtures rich in this constituent are 0.005 to 0.01 too low. To correct this error a screen made of a thin film of 7 per cent antimony iodide and 93 per cent piperine should be used over the eye-piece. Any amber-colored rosin in lumps is suitable.

Per cent Rosin.	00.	10.	20.	30.	40.	50.	60.	70.	80.	90.	100.
Index of refraction	1.683	1.670	1.657	1.643	1.631	1.618	1.604	1.590	1.575	1.560	1.544

All taken from Merwin, Jour. Wash. Acad. of Sc. 3, p. 35, 1913.

OPTICAL CONSTANTS OF METALS.

TABLE 204.

Two constants are required to characterize a metal optically, the refractive index, n, and the absorption index, k, the latter of which has the following significance: the amplitude of a wave after travelling one wave-length, λ^1 measured in the metal, is reduced in the ratio[1] $1 : e^{-2\pi k}$ or for any distance d, $1 : e^{-\frac{2\pi dk}{\lambda^1}}$; for the same wave-length measured in air this ratio becomes $1 : e^{-\frac{2\pi dnk}{\lambda^1}}$. nk is sometimes called the extinction coefficient. Plane polarized light reflected from a polished metal surface is in general elliptically polarized because of the relative change in phase between the two rectangular components vibrating in and perpendicular to the plane of incidence. For a certain angle, $\bar{\phi}$ (principal incidence) the change is 90° and if the plane polarized incident beam has a certain azimuth $\bar{\psi}$ (Principal azimuth) circularly polarized light results. Approximately, (Drude, Annalen der Physik, 36, p. 546, 1889),

$$k = \tan 2\bar{\psi}\,(1 - \cot^2\bar{\phi}) \text{ and } n = \frac{\sin\bar{\phi}\tan\bar{\phi}}{(1+k^2)^{\frac{1}{2}}}\,(1 + \tfrac{1}{2}\cot^2\bar{\phi}).$$

For rougher approximations the factor in parentheses may be omitted. R = computed percentage reflection.

TABLE 205.

(The points have been so selected that a smooth curve drawn through them very closely indicates the characteristics of the metal.)

Metal.	λ	$\bar{\phi}$	$\bar{\psi}$	Computed.				Authority.
				n	k	nk	R	
	μ						%	
Cobalt	0.231	64°31′	29°39	1.10	1.30	1.43	32.	Minor.
	.275	70 22	29 59	1.41	1.52	2.14	46.	"
	.500	77 5	31 53	1.93	1.93	3.72	66.	"
	.650	79 0	31 25	2.35	1.87	4.40	69.	Ingersoll.
	1.00	81 45	29 6	3.63	1.58	5.73	73.	"
	1.50	83 21	26 18	5.22	1.29	6.73	75.	"
	2.25	83 48	26 5	5.65	1.27	7.18	76.	"
Copper	.231	65 57	26 14	1.39	1.05	1.45	29.	Minor.
	.347	65 6	28 16	1.19	1.23	1.47	32.	"
	.500	70 44	33 46	1.10	2.13	2.34	56.	"
	.650	74 16	41 30	0.44	7.4	3.26	86.	Ingersoll.
	.870	78 40	42 30	0.35	11.0	3.85	91.	"
	1.75	84 4	42 30	0.83	11.4	9.46	96.	"
	2.25	85 13	42 30	1.03	11.4	11.7	97.	"
	4.00	87 20	42 30	1.87	11.4	21.3		Först.-Fréed.
	5.50	88 00	41 50	3.16	9.0	28.4		" "
Gold	1.00	81 45	44 00	0.24	28.0	6.7		" "
	2.00	85 30	43 56	0.47	26.7	12.5		" "
	3.00	87 05	43 50	0.80	24.5	19.6		" "
	5.00	88 15	43 25	1.81	18.1	33.		" "
Iridium	1.00	82 10	29 15	3.85	1.60	6.2		" "
	2.00	83 10	29 40	4.30	1.66	7.1		" "
	3.00	81 40	30 40	3.33	1.79	6.0		" "
	5.00	79 00	32 20	2 27	2.03	4.6		" "
Nickel	0.420	72 20	31 42	1.41	1.79	2.53	54.	Tool.
	0.589	76 1	31 41	1.79	1.86	3.33	62.	Drude.
	0.750	78 45	32 6	2.19	1.99	4.36	70.	Ingersoll.
	1.00	80 33	32 2	2.63	2.00	5.26	74.	"
	2.25	84 21	33 30	3.95	2.33	9.20	85.	"
Platinum	1.00	75 30	37 00	1.14	3.25	3.7		Först.-Fréed.
	2.00	74 30	39 50	0.70	5.06	3.5		" "
	3.00	73 50	41 00	0.52	6.52	3.4		" "
	5.00	72 00	42 10	0.34	9.01	3.1		" "
Silver	0.226	62 41	22 16	1.41	0.75	1.11	18.	Minor.
	.293	63 14	18 56	1.57	0.62	0.97	17.	"
	.316	52 28	15 38	1.13	0.38	0.43	4.	"
	.332	52 1	37 2	0.41	1.61	0.65	32.	"
	.395	66 36	43 6	0.16	12.32	1.91	87.	"
	.500	72 31	43 29	0.17	17.1	2.94	93.	"
	.589	75 35	43 47	0.18	20.6	3.64	95.	"
	.750	79 26	44 6	0.17	30.7	5.16	97.	Ingersoll.
	1.00	82 0	44 2	0.24	29.0	6.96	98.	"
	1.50	84 42	43 48	0.45	23.7	10.7	98.	"
	2.25	86 18	43 34	0.77	19.9	15.4	99.	"
	3.00	87 10	42 40	1.65	12.2	20.1		Först.-Fréed.
	4.50	88 20	41 10	4.49	7.42	33.3		" "
Steel	0.226	66 51	28 17	1.30	1.26	1.64	35.	Minor.
	.257	68 35	28 45	1.38	1.35	1.86	40.	"
	.325	69 57	30 9	1.37	1.53	2.09	45.	"
	.500	75 47	29 2	2.09	1.50	3.14	57.	"
	.650	77 48	27 9	2.70	1.33	3.59	59.	Ingersoll.
	1.50	81 48	28 51	3.71	1.55	5.75	73.	"
	2.25	83 22	30 36	4.14	1.79	7.41	80.	"

Drude, Annalen der Physik und Chemie, 39, p. 481, 1890; 42, p. 186, 1891; 64, p. 159, 1898. Minor, Annalen der Physik, 10, p. 581, 1903. Tool, Physical Review, 31, p. 1, 1910. Ingersoll, Astrophysical Journal, 32, p. 265, 1910; Försterling and Fréedericksz, Annalen der Physik, 40, p. 201, 1913.

OPTICAL CONSTANTS OF METALS.

TABLE 206.

Metal.	λ.	n.	k.	R.	Ref.
	μ				
Al.*	0.589	1.44	5.32	83	1
Sb.*	.589	3.04	4.94	70	1
Bi.†‡	white	2.26	–	–	2
Cd.*	.589	1.13	5.01	85	1
Cr.*	.579	2.97	4.85	70	3
Cb.*	.579	1.80	2.11	41	3
Au.†	.257	0.92	1.14	28	4
	.441	1.18	1.85	42	4
	.589	0.47	2.83	82	4
I. crys.	.589	3.34	0.57	30	4
Ir.*	.579	2.13	4.87	75	3
Fe.§	.257	1.01	0.88	16	4
	.441	1.28	1.37	28	4
	.589	1.51	1.63	33	4
Pb.*	.589	2.01	3.48	62	1
Mg.*	.589	0.37	4.42	93	1
Mn.*	.579	2.49	3.89	64	3
Hg. (liq.)	.326	0.68	2.26	66	4
	.441	1.01	3.42	74	4
	.589	1.62	4.41	75	4
	.668	1.72	4.70	77	4
Pd.*	.579	1.62	3.41	65	3
Pt.†	.257	1.17	1.65	37	4
	.441	1.94	3.16	58	4
	.589	2.63	3.54	59	4
	.668	2.91	3.66	59	4
Ni.*	.275	1.09	1.16	24	4
	.441	1.16	1.23	25	4
	.589	1.30	1.97	43	4
Rh.*	0.579	1.54	4.67	78	3
Se.‡	.400	2.94	2.31	44	5
	.490	3.12	1.49	35	5
	.589	2.93	0.45	25	5
	.760	2.60	0.06	20	5
Si.*	.589	4.18	0.09	38	6
	1.25	3.67	0.08	33	6
	2.25	3.53	0.08	31	6
Na. (liq.)	.589	.004	2.61	99	1
Ta.*	.579	2.05	2.31	44	3
Sn.*	.589	1.48	5.25	82	1
W.*	.579	2.76	2.71	49	3
V.*	.579	3.03	3.51	58	3
Zn.*	.257	0.55	0.61	20	4
	.441	0.93	3.19	73	4
	.589	1.93	4.66	74	4
	.668	2.62	5.08	73	4

λ = wave-length, n = refraction index.
k = absorption index, R = reflection.

(1) Drude, see Table 205; (2) Kundt, prism used, Ann. der Physik und Chemie, 34, p. 477, 36, p. 824, 1889; (3) v. Wartenberg, Verh. deutsch. Physik. Ges. 12, p. 105, 1910; (4) Meier, Annales der Physik, 10, p. 581, 1903; (5) Wood, Phil. Mag. (6), 3, 607, 1902; (6) Ingersoll, *see* Table 205.

* solid, † electrolytic, ‡ prism, § deposited as film in vacuo.

TABLE 207.—Reflecting Power of Metals.

Wave-length	Al.	Sb.	Cd.	Co.	Graphite.	Ir.	Mg.	Mo.	Pd.	Rh.	Si.	Ta.	Te.	Sn.	W	Va.	Zn.
μ	Per cents.																
.5		–		–	22	–	72	46		76	34	38	–	–	49	57	–
.6		53		–	24	–	73	48	–	77	32	45	49	–	51	58	–
.8		54		–	25	–	74	52	–	81	29	64	48	–	56	60	–
1.0	71	55	72	67	27	78	74	58	72	84	28	78	50	54	62	61	80
2.0	82	60	87	72	35	87	77	82	81	91	28	90	52	61	85	69	92
4.0	92	68	96	81	48	94	84	90	88	92	28	93	57	72	93	79	97
7.0	96	71	98	93	54	95	91	93	94	94	28	94	68	81	95	88	98
10.0	98	72	98	97	59	96	–	94	97	95	28	–	–	84	96	–	98
12.0	98	–	99	97	–	96	–	95	97	–	–	95	–	85	96	–	99

Coblentz, Bulletin Bureau of Standards, 2, p. 457, 1906, 7, p. 197, 1911. The surfaces of some of the samples were not perfect so that the corresponding values have less weight. The methods for polishing the various metals are described in the original articles.

According to Fresnel the amount of light reflected by the surface of a transparent medium $= \frac{1}{2}(A+B) = \frac{1}{2}\left\{\frac{\sin^2(i-r)}{\sin^2(i+r)} + \frac{\tan^2(i-r)}{\tan^2(i+r)}\right\}$; A is the amount polarized in the plane of incidence; B is that polarized perpendicular to this; i and r are the angles of incidence and refraction.

TABLE 208.—Light reflected when $i = 0°$ or Incident Light is Normal to Surface.

n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.	n.	$\frac{1}{2}(A+B)$.
1.00	0.00	1.4	2.78	2.0	11.11	5.	44.44
1.02	0.01	1.5	4.00	2.25	14.06	5.83	50.00
1.05	0.06	1.6	5.33	2.5	18.37	10.	66.67
1.1	0.23	1.7	6.72	2.75	22.89	100.	96.08
1.2	0.83	1.8	8.16	3.	25.00	∞	100.00
1.3	1.70	1.9	9.63	4.	36.00		

TABLE 209.—Light reflected when n is near Unity or equals $1 + dn$.

i.	A.	B.	$\frac{1}{2}(A+B)$.	$\frac{A-B}{A+B}$.*
0°	1.000	1.000	1.000	0.0
5	1.015	.985	1.000	1.5
10	1.063	.939	1.001	6.2
15	1.149	.862	1.005	14.3
20	1.282	.752	1.017	26.0
25	1.482	.612	1.047	41.5
30	1.778	.444	1.111	60.0
35	2.221	.260	1.240	79.1
40	2.904	.088	1.496	94.5
45	4.000	.000	2.000	100.0
50	5.857	.176	3.016	94.5
55	9.239	1.081	5.160	79.1
60	16.000	4.000	10.000	60.0
65	31.346	12.952	22.149	41.5
70	73.079	42.884	57.981	26.0
75	222.85	167.16	195.00	14.3
80	1099.85	971.21	1035.53	6.2
85	17330.64	16808.08	17069.36	1.5
90	∞	∞	∞	0.0

TABLE 210.—Light reflected when $n = 1.56$.

i.	r.	A.	B.	dA.†	dB.†	$\frac{1}{2}(A+B)$.	$\frac{A-B}{A+B}$.*
° ′	° ′						
0	0 0.0	4.65	4.65	0.130	0.130	4.65	0.0
5	3 13.4	4.70	4.61	.131	.129	4.65	1.0
10	6 25.9	4.84	4.47	.135	.126	4.66	4.0
15	9 36.7	5.09	4.24	.141	.121	4.66	9.1
20	12 44.8	5.45	3.92	.150	.114	4.68	16.4
25	15 49.3	5.95	3.50	.161	.105	4.73	25.9
30	18 49.1	6.64	3.00	.175	.094	4.82	37.8
35	21 43.1	7.55	2.40	.191	.081	4.98	51.7
40	24 30.0	8.77	1.75	.210	.066	5.26	66.7
45	27 8.5	10.38	1.08	.233	.049	5.73	81.2
50	29 37.1	12.54	0.46	.263	.027	6.50	92.9
55	31 54.2	15.43	0.05	.303	.007	7.74	99.3
60	33 58.1	19.35	0.12	.342	—.013	9.73	98.8
65	35 47.0	24.69	1.13	.375	—.032	12.91	91.2
70	37 19.1	31.99	4.00	.400	—.050	18.00	77.7
75	38 32.9	42.00	10.38	.410	—.060	26.19	61.8
80	39 26.8	55.74	23.34	.370	—.069	39 54	41.0
82 30	39 45.9	64.41	34.04	.320	—.067	49.22	30.8
85 0	39 59.6	74.52	49.03	.250	—.061	61.77	20.6
86 0	40 3.6	79.02	56.62	.209	—.055	67.82	16.5
87 0	40 6.7	83.80	65.32	.163	—.046	74.56	12.4
88 0	40 8.9	88.88	75.31	.118	—.036	82.10	8.3
89 0	40 10.2	94.28	86.79	.063	—.022	90.54	4.1
90 0	40 10.7	100.00	100.00	.000	—.000	100.00	0.0

Angle of total polarization $= 57° 10'.3$, $A = 16.99$.

* This column gives the degree of polarization.

† Columns 5 and 6 furnish a means of determining A and B for other values of n. They represent the change in these quantities for a change of n ot 0.01.

Taken from E. C. Pickering's "Applicatioos of Fresoel's Formula for the Reflection of Light."

REFLECTION OF METALS.

TABLE 211. — Perpendicular Incidence and Reflection.

The numbers give the per cents of the incident radiation reflected.

Wave-length, μ.	Silver-backed Glass.	Mercury-backed Glass.	Mach's Magnalium. $69Al+31Mg$.	Brandes-Schünemann Alloy. $32Cu+34Sn+29Ni+5Fe$.	Ross' Speculum Metal. $68.2Cu+31.8Sn$.	Nickel, *Electrolytically Deposited.*	Copper. *Electrolytically Deposited.*	Steel. *Untempered.*	Copper. *Commercially Pure.*	Platinum. *Electrolytically Deposited.*	Gold. *Electrolytically Deposited.*	Brass. *(Trowbridge).*	Silver. *Chemically Deposited.*
.251	-	-	67.0	35.8	29.9	37.8	-	32.9	25.9	33.8	38.8	-	34.1
.288	-	-	70.6	37.1	37.7	42.7	-	35.0	24.3	38.8	34.0	-	21.2
.305	-	-	72.2	37.2	41.7	44.2	-	37.2	25.3	39.8	31.8	-	9.1
.316	-	-	-	-	-	-	-	-	-	-	-	-	4.2
.326	-	-	75.5	39.3	-	45.2	-	40.3	24.9	41.4	28.6		14.6
.338	-	-	-	-		46.5	-	-	-	-	-	-	55.5
.357	-	-	81.2	43.3	51.0	48.8	-	45.0	27.3	43.4	27.9		74.5
.385	-	-	83.9	44.3	53.1	49.6	-	47.8	28.6	45.4	27.1		81.4
.420	-	-	83.3	47.2	56.4	56.6	-	51.9	32.7	51.8	29.3	-	86.6
.450	85.7	72.8	83.4	49.2	60.0	59.4	48.8	54.4	37.0	54.7	33.1	-	90.5
.500	86.6	70.9	83.3	49.3	63.2	60.8	53.3	54.8	43.7	58.4	47.0	-	91.3
.550	88.2	71.2	82.7	48.3	64.0	62.6	59.5	54.9	47.7	61.1	74.0	-	92.7
.600	88.1	69.9	83.0	47.5	64.3	64.9	83.5	55.4	71.8	64.2	84.4	-	92.6
.650	89.1	71.5	82.7	51.5	65.4	66.6	89.0	56.4	80.0	66.5	88.9	-	94.7
.700	89.6	72.8	83.3	54.9	66.8	68.8	90.7	57.6	83.1	69.0	92.3	-	95.4
.800	-	-	84.3	63.1	-	69.6		58.0	88.6	70.3	94.9	-	96.8
1.0	-	-	84.1	69.8	70.5	72.0	-	63.1	90.1	72.9	-	-	97.0
1.5	-	-	85.1	79.1	75.0	78.6	-	70.8	93.8	77.7	97.3	-	98.2
2.0	-	-	86.7	82.3	80.4	83.5		76.7	95.5	80.6	96.8	91.0	97.8
3.0	-	-	87.4	85.4	86.2	88.7	-	83.0	97.1	88.8	-	93.7	98.1
4.0	-	-	88.7	87.1	88.5	91.1		87.8	97.3	91.5	96.9	95.7	98.5
5.0	-	-	89.0	87.3	89.1	94.4		89.0	97.9	93.5	97.0	95.9	98.1
7.0	-	-	90.0	88.6	90.1	94.3	-	92.9	98.3	95.5	98.3	97.0	98.5
9.0	-	-	90.6	90.3	92.2	95.6	-	92.9	98.4	95.4	98.0	97.8	98.7
11.0	-	-	90.7	90.2	92.9	95.9	-	94.0	98.4	95.6	98.3	96.6	98.8
14.0	-	-	92.2	90.3	93.6	97.2	-	96.0	97.9	96.4	97.9	-	98.3

Based upon the work of Hagen and Rubens, Ann. der Phys. (1) 352, 1900; (8) 1, 1902; (11) 873, 1903. Taken partly from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 212. — Percentage Diffuse Reflection from Miscellaneous Substances.

Wave-length μ	Lamp-blacks.					Pt. black electrol.	Green leaves.	Lead oxide.	Al. oxide.	Zinc oxide.	White Paper.	Lead carbonate.	Asphalt.	Black velvet.	Black felt.	Red brick.
	Paint.	Rosin.	Sperm candle.	Acetylene	Camphor.											
*.60	3.2						25.	52.	84.	82.		89.	15.	1.8	14.	30.
*.95	3.4	1.3	1.1	0.6	1.3	1.1			88.	86.	75.	93.			21.	
4.4	3.2	1.3	.9	.8	1.2	1.4		51.	21.	8.	18.	29.		3.7		
8.8	3.8		1.3	1.2	1.6	2.1		26.	2.	3.	5.	11.		2.7		12.
24.0	4.4	3.0	4.0	2.1	5.7	4.2		10.	6.	5.		7.				

*Not monochromatic (max.) means from Coblentz, J. Franklin Inst. 1912. Bulletin Bureau of Standards, 9, p. 283, 1912, contains many other materials.

TRANSMISSIBILITY FOR RADIATION OF JENA GLASSES.

TABLE 213.

Coefficients, a, in the formula $I_t = I_0 a^t$, where I_0 is the Intensity before, and I_t after, transmission through the thickness t, expressed in centimeters. Deduced from observations by Müller, Vogel, and Rubens as quoted in Hovestadt's Jena Glass (English translation).

Type of Glass.	Coefficient of transmission, a.									
λ =	.375 μ	390 μ	.400 μ	.434 μ	.436 μ	.455 μ	.477 μ	.503 μ	.580 μ	.677 μ
O 340, Ord. light flint	.388	.456	.614	.569	.680	.834	.880	.880	.878	.939
O 102, H'vy silicate flint	–	.025	.463	.502	.566	.663	.700	.782	.828	.794
O 93, Ord. " "	–	–	–	–	.714	.807	.899	.871	.903	.943
O 203, " " crown	.583	.583	.695	.667	.806	.822	.860	.872	.872	.903
O 598, (Crown)	–	–	–	–	.797	.770	.771	.776	.818	.860
λ =	0.7 μ	0.95 μ	1.1 μ	1.4 μ	1.7 μ	2.0 μ	2.3 μ	2.5 μ	2.7 μ	2.9 μ	3.1 μ
S 204, Borate crown	1.00	.99	.94	.90	.85	.81	.69	.43	.29	.18	–
S 179, Med. phosp. cr.	–	.98	.95	.90	.84	.67	.49	.87	.18		–
O 1143, Dense, bor. sil. cr.	.98	–	.97	–	.95	.93	.90	.84	.71	.47	.27
O 1092, Crown	.99	.96	.95	.99	.99	.91	.82	.71	.60	.48	.29
O 1151, "	.98	–	.99	.99	.98	.94	.90	.79	.75	.45	.32
O 451, Light flint	1.00		.99	–	.98	.95	.92	.84	.78	.54	.34
O 469, Heavy "	1.00	–	.98	–	.99	.98	.98	.97	.90	.66	.50
O 500, " "	1.00	–	1.00	–	1.00	–	1.00	.99	.92	.74	.53
S 163, " "	1.00	–	.98	–	.99	–	.99	–	.94	.78	.60

TABLE 214.

Note: With the following data, t must be expressed in millimeters; i. e. the figures as given give the transmissions for thickness of 1 mm.

No. and Type of Glass.	Wave-length in μ. Visible Spectrum.							Ultra-violet Spectrum.					
	.644 μ	.578 μ	.546 μ	.509 μ	.480 μ	.436 μ	.405 μ	.384 μ	.361 μ	.340 μ	.332 μ	.309 μ	.280 μ
F 3815 Dark neutral	.35	.35	.37	.35	.34	.30	.15	.06					
F 4512 Red filter	.94	.05											
F 2745 Copper ruby	.72	.39	.47	.47	.45	.43	.43						
F 4313 Dark yellow	.98	.97	.93	.83	.09								
F 4351 Yellow	.98	.97	.96	.93	.44	.15							
F 4937 Bright yellow	1.0	1.0	1.0	.99	.74	.40	.31	.28	.22	.18	.14	.06	
F 4930 Green filter	.17	.50	.64	.62	.44								
F 3873 Blue filter	–	–	–	.18	.50	.73	.69	.59	.36	.10			
F 3654 Cobalt glass, transparent for outer red	–	–	–	.15	.44	.85	1.0	1.0	1.0	1.0	1.0	.58	
F 3653 Blue, ultraviolet	–	–	–	–	.11	.65	1.0	1.0	1.0	1.0	1.0	.81	.18
F 3728 Didymium, str'g bands	.99	.72	.99	.96	.95	.96	.99	.99	.89	.89	.77	.54	

This and the following table are taken from Jenaer Glas für die Optik, Liste 751, 1909

TABLE 215. — Transmissibility of Jena Ultra-violet Glasses.

No. and Type of Glass.	Thickness.	0.397 μ	0.383 μ	0.361 μ	0.346 μ	0.325 μ	0.309 μ	0.280 μ
UV 3199 Ultra-violet	1 mm.	1.00	1.00	1.00	1.00	1.00	0.95	0.56
" "	2 mm.	0.99	0.99	0.99	0.97	0.90	0.57	
" "	1 dm.	0.95	0.95	0.89	0.70	0.36		
UV 3248 "	1 mm.	1.00	1.00	1.00	1.00	0.98	0.91	0.35
" "	2 mm.	0.98	0.98	0.98	0.92	0.78	0.38	
" "	1 dm.	0.96	0.87	0.79	0.45	0.08		

TABLE 216.

TRANSMISSIBILITY FOR RADIATION.

Transmissibility of the Various Substances of Tables 166 to 175.

Alum: Ordinary alum (crystal) absorbs the infra-red.
Metallic reflection at 9.05μ and 30 to 40μ.

Rock-salt: Rubens and Trowbridge (Wied. Ann. 65, 1898) give the following transparencies for a 1 cm. thick plate in %:

λ	9	10	12	13	14	15	16	17	18	19	20.7	23.7μ
%	99.5	99.5	99.3	97.6	93.1	84.6	66.1	51.6	27.5	9.6	0.6	0.

Pflüger (Phys. Zt. 5. 1904) gives the following for the ultra-violet, same thickness: 280μμ, 95.5%; 231, 86%; 210, 77%; 186, 70%.
Metallic reflection at 0.110μ, 0.156, 51.2, and 87μ.

Sylvine: Transparency of a 1 cm. thick plate (Trowbridge, Wied. Ann. 60, 1897).

λ	9	10	11	12	13	14	15	16	17	18	19	20.7	23.7μ
%	100.	98.8	99.0	99.5	99.5	97.5	95.4	93.6	92.	86.	76.	58.	15.

Metallic reflection at 0.114μ, 0.161, 61.1, 100.

Fluorite: Very transparent for the ultra-violet nearly to 0.1μ.
Rubens and Trowbridge give the following for a 1 cm. plate (Wied. Ann. 60, 1897):

λ	8μ	9	10	11	12μ
%	84.4	54.3	16.4	1.0	0

Metallic reflection at 24μ, 31.6, 40μ.

Iceland Spar: Merritt (Wied. Ann. 55, 1895) gives the following values of *k* in the formula $i = i_0 e^{-kd}$ (d in cm.):
For the ordinary ray:

λ	1.02	1.45	1.72	2.07	2.11	2.30	2.44	2.53	2.60	2.65	2.74μ
k	0.0	0.0	0.03	0.13	0.74	1.92	3.00	1.92	1.21	1.74	2.36

λ	2.83	2.90	2.95	3.04	3.30	3.47	3.62	3.80	3.98	4.35	4.52	4.83μ
k	1.32	0.70	1.80	4.71	22.7	19.4	9.6	18.6	∞	6.6	14.3	6.1

For the extraordinary ray:

λ	2.49	2.87	3.00	3.28	3.38	3.59	3.76	3.90	4.02	4.41	4.67μ
k	0.14	0.08	0.43	1.32	0.89	1.79	2.04	1.17	0.89	1.07	2.40

λ	4.91	5.04	5.34	5.50μ
k	1.25	2.13	4.41	12.8

Quartz: Very transparent to the ultra-violet; Pflüger gets the following transmission values for a plate 1 cm. thick: at 0.222μ, 94.2%; 0.214, 92; 0.203, 83.6; 0.186, 67.2%.
Merritt (Wied. Ann. 55, 1895) gives the following values for *k* (see formula under Iceland Spar):
For the ordinary ray:

λ	2.72	2.83	2.95	3.07	3.17	3.38	3.67	3.82	3.96	4.12	4.50μ
k	0.20	0.47	0.57	0.31	0.20	0.15	1.26	1.61	2.04	3.41	7.30

For the extraordinary ray:

λ	2.74	2.89	3.00	3.08	3.26	3.43	3.52	3.59	3.64	3.74	3.91	4.19	4.36μ
k	0.0	0.11	0.33	0.26	0.11	0.51	0.76	1.88	1.83	1.62	2.22	3.35	8.0

For λ > 7 μ, becomes opaque, metallic reflection at 8.50μ, 9.02, 20.75–24.4μ, then transparent again.

The above are taken from Kayser's "Handbuch der Spectroscopie," vol. iii.

TRANSMISSIBILITY OF RADIATION.

TABLE 217. — Color Screens.

The following light-filters are quoted from Landolt's "Das optische Drehungsvermögen, etc." 1898. Although only the potassium salt does not keep well it is perhaps safer to use freshly prepared solutions.

Color.	Thickness. mm.	Water solutions of	Grammes of substance in 100 c.cm.	Optical centre of band. μ	Transmission.
Red	20	Crystal-violet, 5BO	0.005	0.6659	begins about 0.718μ.
"	20	Potassium monochromate	10.		ends sharp at 0.639μ.
Yellow	20	Nickel-sulphate, $NiSO_4.7aq.$	30.	0.5919	0.614–0.574μ,
"	15	Potassium monochromate	10.		
"	15	Potassium permanganate	0.025		
Green	20	Copper chloride, $CuCl_2.2aq.$	60.	0.5330	0.540–0.505μ
"	20	Potassium monochromate	10.		
Bright blue	20	Double-green, SF	0.02	0.4885	0.526–0.494 and
	20	Copper-sulphate, $CuSO_4.5aq.$	15.		0.494–0.458μ
Dark blue	20	Crystal-violet, 5BO	0.005	0.4482	0.478–0.410μ
	20	Copper sulphate, $CuSO_4.5aq.$	15.		

TABLE 218. — Color Screens.

The following list is condensed from Wood's Physical Optics :

Methyl violet, 4R· (Berlin Anilin Fabrik) very dilute, and nitroso-dimethyl-aniline transmits 0.365μ. Methyl violet + chinin-sulphate (separate solutions), the violet solution made strong enough to blot out 0.4359μ, transmits 0.4047 and 0.4048, also faintly 0.3984.

Cobalt glass + aesculin solution transmits 0.4359μ.

Guinea green B extra (Berlin) + chinin sulphate transmits 0.4916μ.

Neptune green (Bayer, Elberfeld) + chrysoidine. Dilute the latter enough to just transmit 0.5790 and 0.5461 ; then add the Neptune green until the yellow lines disappear.

Chrysoidine + eosine transmits 0.5790μ. The former should be dilute and the eosine added until the green line disappears.

Silver chemically deposited on a quartz plate is practically opaque except to the ultra-violet region 0.3160–0.3260 where 90% of the energy passes through. The film should be of such thickness that a window backed by a brilliantly lighted sky is barely visible.

In the following those marked with a * are transparent to a more or less degree to the ultra-violet:

* Cobalt chloride: solution in water, — absorbs 0.50–.53μ; addition of $CaCl_2$ widens the band to 0.47–.50. It is exceedingly transparent to the ultra-violet down to 0.20. If dissolved in methyl alcohol + water, absorbs 0.50–.53 and everything below 0.35. In methyl alcohol alone 0.485–0.555 and below 0.40μ.

Copper chloride: in ethyl alcohol absorbs above 0.585 and below 0.535 ; in alcohol + 50% water, above 0.595 and below 0.37μ.

Neodymium salts are useful combined with other media, sharpening the edges of the absorption bands. In solution with bichromate of potash, transmits 0.535–.565 and above 0.60μ, the bands very sharp (a useful screen for photographing with a visually corrected objective).

Praesodymium salts : three strong bands at 0.482, .468, .444. In strong solutions they fuse into a sharp band at 0.435–.485μ. Absorption below 0.34.

Picric acid absorbs 0.36–.42μ, depending on the concentration.

Potassium chromate absorbs 0.40–.35, 0.30–.24, transmits 0.23μ.

* Potassium permanganate: absorbs 0.555–.50, transmits all the ultra-violet.

Chromium chloride: absorbs above 0.57, between 0.50 and .39, and below 0.33μ. These limits vary with the concentration.

Aesculin: absorbs below 0.363μ, very useful for removing the ultra-violet.

* Nitroso-dimethyl-aniline: very dilute aqueous solution absorbs 0.49–.37 and transmits all the ultra-violet.

Very dense cobalt glass + dense ruby glass or a strong potassium bichromate solution cuts off everything below 0.70 and transmits freely the red.

Iodine: saturated solution in CS_2 is opaque to the visible and transparent to the infra-red.

TRANSMISSIBILITY OF RADIATION.

TABLE 219. — Color Screens. Jena Glasses.

	Kind of Glass.	Maker's No.	Color.	Region Transmitted.	Thickness. mm.
1	Copper-ruby . .	2728	Deep red	Only red to 0.6μ	1.7
1a	Gold-ruby . . .	459^III	Red	Red, yellow; in thin layers also blue and violet.	
2	Uranium . . .	454^III	Bright yellow . . .	Red, yellow, green to E_b; in thin layer also blue	16.
2a	"	455^III	Bright yellow, fluoresces.		
3	Nickel	440^III	Bright yellow-brown	Red, yellow, green (weakened), blue (very weakened)	11.
4	Chromium . .	414^III	Yellow-green . . .	Yellowish-green	10.
4a	"	433^III	Greenish-yellow . .	Red, green; from 0.65–.50μ . . .	5.
4b	Green copper. .	431^III	Green.	Green, yellow, some red and blue .	2–3
5	Chromium. . .	432^III	Yellow-green . . .	Yellowish-green, some red . . .	2.5
6	Copper chromium	436^III	Grass-green . . .	Green	5.
7	Green-filter . .	437^III	Dark green	Green (in thin sheets some blue) .	5.
8	" " . . .	438^III	" "	Green	
10	Copper	2742	Blue, as $CuSO_4$ . .	Green, blue, violet	5–12
11	Blue-violet . .	447^III	Blue, as cobalt glass	Blue, violet	5.
"	" " . . .	"	" " " " .	Blue, violet, blue-green (weakened), *no red*	2–5
12	Cobalt	424^III	Blue	Blue, violet, extreme red	4–5
13	Nickel	450^III	Dark violet	Violet (G–H), extreme red . . .	6.
14	Violet	452^III	" "	Violet (G–H), some weakened . .	7.
15	Gray	444^III	Gray, no recognizable color	All parts of the spectrum weakened	0.1–8
16	"	445^III			0.1–3

See "Über Farbgläser für wissenschaftliche und technische Zwecke," by Zsigmondy, Z. für Instrumentenkunde, 21, 1901 (from which the above table is taken), and "Über Jenenser Lichtfilter," by Grebe, same volume.

(The following notes are quoted from Everett's translation of the above in the English edition of Hovestadt's "Jena Glass.")

Division of the spectrum into complementary colors:

1st by 2728 (deep red) and 2742 (blue, like copper sulphate).
2nd by 454^III (bright yellow) and 447^III (blue, like cobalt glass).
3rd by 433^III (greenish-yellow) and 424^III (blue).

Thicknesses necessary in above: 2728, 1.6–1.7 mm.; 2742, 5; 454^III, 16; 447^III, 1.5–2.0; 433^III, 2.5–3.5; 424^III, 3 mm.

Three-fold division into red, green and blue (with violet):

2728, 1.7 mm.; 414^III, 10 mm.; 447^III, 1.5 mm., or by
2728, 1.7 mm.; 436^III, 2.6 mm.; 447^III, 1.8 mm.

Grebe found the three following glasses specially suited for the additive methods of three-color projection:

2745, red; 438^III, green; 447^III, blue violet;

corresponding closely to Young's three elementary color sensations.

Most of the Jena glasses can be supplied to order, but the absorption bands vary somewhat in different meltings.

See also "Atlas of Absorption Spectra," Uhler and Wood, Carnegie Institution Publications, 1907.

TABLE 219a. — Water Vapor.

Values of a in $I = I_0 e^{ad}$, d in c. m. I_0; I, intensity before and after transmission.

Wave-length μ,	.186	.193	.200	.210	.220	.230	.240	.260	.300	.415
a	.0688	.0165	.009	.0061	.0057	.0034	.0032	.0025	.0015	.00035
Wave-length μ,	.430	.450	.487	.500	.550	.600	.650	.779	.865	.945
a	.00023	.0002	.0001	.0002	.0003	.0016	.0025	.272	.296	.538

First 9; Kreusler, Drud. Ann. 6, 1901,; next Ewan, Proc. R. Soc. 57, 1894, Aschkinass, Wied Ann. 55, 1895; last 3, Nichols, Phys. Rev. 1, 1.
See Rubens, Ladenburg. Verh. D. Phys. Ges. 1911, for extinction coefs., reflective power and index of refraction, 1 μ to 18 μ.

TABLE 220. — Tartaric Acid; Camphor; Santonin; Santonic Acid; Cane Sugar.

A few examples are here given showing the effect of wave-length on the rotation of the plane of polarization. The rotations are for a thickness of one decimeter of the solution. The examples are quoted from Landolt & Börnstein's "Phys. Chem. Tab." The following symbols are used:—

p = number grams of the active substance in 100 grams of the solution.
c = " " solvent " " " "
q = " " active " " cubic centimeter "

Right-handed rotation is marked +, left-handed —.

Line of spectrum.	Wave-length according to Ångström in cms. × 10⁶.	Tartaric acid,* CuH_6O_6, dissolved in water. q = 50 to 95, temp. = 24° C.	Camphor,* $C_{10}H_{16}O$, dissolved in alcohol. q = 50 to 95, temp. = 22.9° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in chloroform. q = 75 to 96.5, temp. = 20° C.
B	68.67			— 140°.1 + 0.2085 q
C	65.62	+ 2°.748 + 0.09446 q	38°.549 — 0.0852 q	— 149.3 + 0.1555 q
D	58.92	+ 1.950 + 0.13030 q	51.945 — 0.0964 q	— 202.7 + 0.3086 q
E	52.69	+ 0.153 + 0.17514 q	74.331 — 0.1343 q	— 285.6 + 0.5820 q
b_1	51.83	– –	– –	— 302.38 + 0.6557 q
b_2	51.72	— 0.832 + 0.19147 q	79.348 — 0.1451 q	– –
F	48.61	— 3.598 + 0.23977 q	99.601 — 0.1912 q	— 365.55 + 0.8284 q
e	43.83	— 9.657 + 0.31437 q	149.696 — 0.2346 q	— 534.98 + 1.5240 q

		Santonin,† $C_{15}H_{18}O_3$,* dissolved in alcohol. c = 1.782. temp. = 20° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in alcohol. c = 4.046. temp. = 20° C.	Santonin,† $C_{15}H_{18}O_3$, dissolved in chloroform c = 3.1–30.5. temp. = 20° C.	Santonic acid,† $C_{15}H_{20}O_4$, dissolved in chloroform. c = 27.192. temp. = 20° C.	Cane sugar,‡ $C_{12}H_{22}O_{11}$, dissolved in water. p = 10 to 30.
B	68.67	— 110.4°	442°	484°	— 49°	47°.56
C	65.62	— 118.8	504	549	— 57	52.70
D	58.92	— 161.0	693	754	— 74	60.41
E	52.69	— 222.6	991	1088	— 105	84.56
b_1	51.83	— 237.1	1053	1148	— 112	–
b_2	51.72	–	–	–	–	87.88
F	48.61	— 261.7	1323	1444	— 137	101.18
e	43.83	— 380.0	2011	2201	— 197	
G	43.07	–	–	–	–	131.96
g	42.26	–	2381	2610	— 230	–

* Arndtsen, "Ann. Chim. Phys." (3) 54, 1858.
† Narini, "R. Acc. dei Lincei," (3) 13, 1882.
‡ Stefan, "Sitzb. d. Wien. Akad." 52, 1865.

TABLE 221. — Sodium Chlorate; Quartz.

Sodium chlorate (Guye, C. R. 108, 1889).				Quartz (Soret & Sarasin, Arch. de Gen. 1882, or C. R. 95, 1882).*					
Spectrum line.	Wave-length.	Temp. C.	Rotation per mm.	Spectrum line.	Wave-length.	Rotation per mm.	Spectrum line.	Wave-length.	Rotation per mm.
a	71.769	15°.0	2°.068	A	76.04	12°.668	Cd_9	36.090	63°.628
B	67.889	17.4	2.318	a	71.836	14.304	N	35.818	64.459
C	65.073	20.6	2.599	B	68.671	15.746	Cd_{10}	34.655	69.454
D	59.085	18.3	3.104				O	34.406	70.587
E	53.233	16.0	3.841	C	65.621	17.318			
F	48.912	11.9	4.587	D_1	58.951	21.684	Cd_{11}	34.015	72.448
G	45.532	10.1	5.331	D_2	58.891	21.727	P	33.600	74.571
G	42.834	14.5	6.005				Q	32.858	78.579
H	40.714	13.3	6.754	E	52.691	27.543	Cd_{12}	32.470	80.459
L	38.412	14.0	7.654	F	48.607	32.773			
M	37.352	10.7	8.100	G	43.072	42.604	R	31.798	84.972
N	35.818	12.9	8.861				Cd_{17}	27.467	121.052
P	33.931	12.1	9.801	h	41.012	47.481	Cd_{18}	25.713	143.266
Q	32.341	11.9	10.787	H	39.681	51.193	Cd_{23}	23.125	190.426
R	30.645	13.1	11.921	K	39.333	52.155			
T	29.918	12.8	12.424				Cd_{24}	22.645	201.824
Cd_{17}	28.270	12.2	13.426	L	38.196	55.625	Cd_{25}	21.935	220.731
Cd_{18}	25.038	11.6	14.965	M	37.262	58.894	Cd_{26}	21.431	235.972

* The paper is quoted from a paper by Ketteler in "Wied. Ann." vol. 21, p. 444. The wave-lengths are for the Fraunhofer lines, Ångström's values for the ultra violet sun, and Cornu's values for the cadmium lines.

Table 222.

NEWTON'S RINGS.

Newton's Table of Colors.

The following table gives the thickness in millionths of an inch, according to Newton, of a plate of air, water, and glass corresponding to the different colors in successive rings commonly called colors of the first, second, third, etc., orders.

Order.	Color for reflected light.	Color for transmitted light.	Thickness in millionths of an inch for — Air.	Water.	Glass.
I.	Very black	—	0.5	0.4	0.2
	Black . .	White . .	1.0	0.75	0.9
	Beginning of black .	—	2.0	1.5	1.3
	Blue . .	Yellowish red . .	2.4	1.8	1.5
	White . .	Black . .	5.2	3.9	3.4
	Yellow . .	Violet .	7.1	5.3	4.6
	Orange .	—	8.0	6.0	4.2
	Red . . .	Blue . .	9.0	6.7	5.8
II.	Violet . .	White .	11.2	3.4	7.2
	Indigo . .	—	12.8	9.6	8.4
	Blue . .	Yellow .	14.0	10.5	9.0
	Green . .	Red . .	15.1	11.3	9.7
	Yellow . .	Violet .	16.3	12.2	10.4
	Orange .	—	17.2	13.0	11.3
	Bright red	Blue . .	18.2	13.7	11.8
	Scarlet . .	—	19.7	14.7	12.7
III.	Purple . .	Green .	21.0	15.7	13.5
	Indigo . .	—	21.1	17.6	14.2
	Blue . .	Yellow .	23.2	17.5	15.1
	Green . .	Red . .	25.2	18.6	16.2

Order.	Color for reflected light.	Color for transmitted light.	Thickness in millionths of an inch for — Air.	Water.	Glass.
	Yellow . .	Bluish green	27.1	20.3	17.5
	Red . . .	—	29.0	21.7	18.7
	Bluish red	—	32.0	24.0	20.7
IV.	Bluish green .	—	24.0	25.5	22.0
	Green . .	Red .	35.3	26.5	22.7
	Yellowish green .	—	36.0	27.0	23.2
	Red . . .	Bluish green	40.3	30.2	26.0
V.	Greenish blue . .	Red .	46.0	34.5	39.7
	Red . . .	—	52.5	39.4	34.0
VI.	Greenish blue . .	—	58.7	46	38.0
	Red . . .	—	65.0	48.7	42.0
VII.	Greenish blue . .	—	72.0	53.2	45.8
	Reddish white .	—	71.0	57.7	49.4

The above table has been several times revised both as to the colors and the numerical values. Professors Reinold and Rucker, in their investigations on the measurement of the thickness of soap films, found it necessary to make new determinations. They give a shorter series of colors, as they found difficulty in distinguishing slight differences of shade, but divide each color into ten parts and tabulate the variation of thickness in terms of the tenth of a color band. The position in the band at which the thickness is given and the order of color are indicated by numerical subscripts. For example: $R_{1\,5}$ indicates the red of the first order and the fifth tenth from the edge furthest from the red edge of the spectrum. The thicknesses are in millionths of a centimeter.

Order.	Color.	Position.	Thickness.
I.	Red * .	$R_{1\,5}$	28.4
II.	Violet .	$V_{2\,5}$	30.5
	Blue . .	$B_{2\,5}$	35.3
	Green .	$G_{2\,5}$	40.9
	Yellow *	$Y_{2\,5}$	45.4
	Orange *	$O_{2\,5}$	49.1
	Red . .	$R_{2\,5}$	52.2
III.	Purple .	$P_{3\,5}$	55.9
	Blue . .	$B_{3\,0}$	57.7
	Blue * .	$B_{3\,5}$	60.3
	Green .	$G_{3\,5}$	65.6
	Yellow *	$Y_{3\,5}$	71.0

Order.	Color.	Position.	Thickness.
	Red * .	$R_{3\,5}$	76.5
	Bluish red * .	$BR_{3\,5}$	81.5
IV.	Green .	$G_{4\,0}$	84.1
	" .	$G_{4\,5}$	89.3
	Yellow green *	$YG_{4\,5}$	96.4
	Red * .	$R_{4\,5}$	105.2
V.	Green .	$G_{5\,0}$	111.9
	Green *.	$G_{5\,5}$	118.8
	Red . .	$R_{5\,0}$	126.0
	Red * .	$R_{5\,5}$	133.5

Order.	Color.	Position.	Thickness.
VI.	Green .	$G_{6\,0}$	141.0
	Green *	$G_{6\,5}$	147.9
	Red . .	$R_{6\,0}$	154.8
	Red * .	$R_{6\,5}$	162.7
VII.	Green .	$G_{7\,0}$	170.5
	Green *.	$G_{7\,5}$	178.7
	Red . .	$R_{7\,0}$	186.9
	Red * .	$R_{7\,5}$	193.6
VIII.	Green .	$G_{8\,0}$	200.4
	Red . .	$R_{8\,0}$	211.5

* The colors marked are the same as the corresponding colors in Newton's table.

TABLE 223.

CONDUCTIVITY FOR HEAT.

The coefficient k is the quantity of heat in small calories which is transmitted per second through a plate one centimeter thick per square centimeter of its surface when the difference of temperature between the two faces of the plate is one degree Centigrade. The coefficient k is found to vary with the absolute temperature of the plate, and is expressed approximately by the equation $k_t = k_0 [1 + \alpha (t - t_0)]$. k_0 is the resistance at t_0, the lower temperature of the bracketed pairs in the table, k_t that at temperature t and α is a constant.

Substance.	t	k_t	α	Authority.
Aluminum	18	0.480	.00030	2
	100	.492		
Antimony	0	.0442	—.001041	1
	100	.0396		
Bismuth	18	.0194	—.0021	2
	100	.0161		
Brass (yellow)	0	.2041	.002445	1
	100	.2540		
" (red)	0	.2460	.001492	1
	100	.2827		
Cadmium	18	.222	—.00038	2
	100	.215		
Constantin 60Cu+40Ni	18	.5402	.00227	2
	100	.6405		
Copper	18	.918	—.00013	2
	100	.908		
German silver	0	.0700	.002670	1
	100	.0887		
Iron (cast)	18	.108	—.0001	2
	100	.108		
" (wrought)	18	.144	—.0001	2
	100	.142		
Lead	18	.083	—.0001	2
	100	.076		
Mercury	0	.0148	.0055	4
	50	.0189		
Magnesium	0–100	.3760	–	1
Manganin 84Cu+4Ni+12Mn	18	.5186	+.0026	2
	100	.6310		
Nickel	18	.1420	–	2
Palladium	18	.1683	–	2
Platinum	18	.1664	+.00051	2
	100	.1733		
Steel (hard)	–	.0620	–	5
" (soft)	–	.1110	–	5
Silver	18	1.006	—.00017	2
	100	.992		
Tin	0	.1528	—.000687	1
	100	.1423		
Wood's alloy	–	.0319	–	4
Zinc	18	.2653	—.00016	2
	100	.2619		
Concrete (cinder)	–	.00081	–	–
" (stone)	–	.0022	–	3

Substance.	t	k_t	Authority.
Carborundum		.00050	1
Slate	–	.0036	1
Soil dry	–	.00033	11
" wet	–	.0016	11
Diatomic earth	–	.00013	12
Fire-brick	–	.00028	12
Granite from		.00510	6
to	–	.00550	
Lime	–	.00029	12
Magnesia from	–	.00016	12
to	–	.00045	
Marbles, limestone, calcite, compact dolomite from		.00470	6
to		.00560	
Micaceous flagstone:			
along cleavage	–	.00632	6
across cleavage	–	.00441	6
Paraffine	–	.00014	8
	0	.00023	9
	100	.00168	9
Pasteboard	–	.00045	8
Plaster of Paris	–	.00070	11
" " " powder	–	.0026	11
Quartz		.00036	12
Sand (white dry)	–	.00093	6
Sandstone and hard grit (dry) from	–	.00545	6
to	–	.00565	
Sawdust	–	.00012	8
Serpentine (Cornwall red)	–	.00441	6
Slate:			
along cleavage from		.00550	6
to	–	.00650	
across cleavage from	–	.00315	6
to	–	.00360	
Snow, compact layers	–	.00051	7
Strawboard	–	.00033	8
Vulcanite	–	.00087	10
Vulcanized rubber (soft) from	–	.00034	6
to	–	.00054	6
Wax (bees)	–	.00009	8
Wood, fir:			
parallel to axis	–	.00030	8
perpendicular to axis	–	.00009	8

1 Lorenz.
2 J + D*.
3 Norton.
4 H. F. Weber.
5 Kohlrausch.
6 H. L. & D.†
7 Hjeltström.
8 G. Forbes.
9 R. Weber.
10 Stefan.
11 Lees-Chorlton.
12 Hutton-Blard.

* Jaeger and Diesselhorst.

† Herschel, Lebour, and Dunn (British Association Committee).

TABLE 224.

THERMAL CONDUCTIVITIES AT HIGH TEMPERATURES.

Material.	Authority.	Temperature Centigrade Degrees.	Thermal Conductivity Calories per sec. per deg. C. per cm. cube.	
Nickel	Angell[1]	300	.126	
		400	.117	
		600	.088	
		700	.069	
		800	.068	
		1000	.064	
		1200	.058	
Aluminum	Angell[1]	100	.49	
		200	.55	
		300	.64	
		400	.76	
		600	1.01	
Iron	Hering	100 – 727	.202	
		100 – 912	.184	
		100 – 1245	.191	
Copper	Hering	100 – 197	1.043	
		100 – 268	.969	
		100 – 370	.931	
		100 – 541	.902	
		100 – 837	.858	
Graphite (Artificial)	Hering	100 – 390	.338	
		100 – 546	.324	
		100 – 720	.306	
		100 – 914	.291	
	Hansen[2]	30 – 2830	.162	
		2800 – 3200	.002	
			maximum.	minimum.
Amorphous Carbon	Hansen[2]	90 – 110	.55	.45
		180 – 220	.44	.34
		350 – 450	.35	.26
		500 – 700	.31	.22
		37 – 163	.028	.003
		170 – 330	.027	.004
		240 – 523	.020	.003
		283 – 597	.011	.004
	Hering	100 – 360	.089	
		100 – 751	.124	
		100 – 842	.129	
Graphite brick	Wologdine	300 – 700	.024	
Carborundum brick	"	150 – 1200	.0032 to .027	
Magnesia brick	"	50 – 1130	.0027 to .0072	
Gas retort brick	"	100 – 1125	.0038	
Building and terra cotta	"	15 – 1100	.0018 to .0038	
Silica brick	"	100 – 1000	.002 to .0033	
Stoneware mixtures	"	70 – 1000	.0029 to .0053	
Porcelain (Sèvres)	"	165 – 1055	.0039 to .0047	
Fire clay brick	"	125 – 1220	.0032 to .0054	
Limestone	Poole[3]	40	.0046 to .0057	
		100	.0039 to .0049	
		350	.0032 to .0035	
Granite	Poole[3]	100	.0045 to .0050	
		200	.0043 to .0097	
		500	.0040	

Angell, Phys. Rev. 33, p. 421, 1911; Clement, Egy, Eng. Exp. Univers. of Ill., Bul. 36, 1909; Dewey, Progressive Age, 27, p. 772, 1909; Hering, Trans. Am. Inst. Elect. Eng. 1910; Poole, Phil. Mag. 24, p. 45, 1912; Wologdine, Bull. Soc. Encouragement, 111, p. 879, 1909; Electroch. and Met. Ind. 7, pp. 383, 433, 1909; Woolson, Eng. News, 58, p. 166, 1907; heat transmission by concretes. Actual values not given; Hansen, Trans. Amer. Electrochem. Soc. 16, p. 329, 1909; Richards, Met. and Chem. Eng. 11, p. 575, 1913.

[1] Taken from Angell's curves.
[2] Values calculated from results expressed in other units. The max. and min. do not relate to variability in material, but to possible errors in the method.
[3] Taken from Poole's curves.

CONDUCTIVITY FOR HEAT.

TABLE 225. — Various Substances.

Substance.	t o	k_t	Authority.
Asbestos paper		.00043	5
Blotting paper	–	.00015	5
Carbon	0	.000405	1
Portland cement	–	.00071	5
Cork	0	.000717	1
Cotton wool	0	.000043	1
Cotton pressed	–	.000033	1
Chalk	–	.002000	2
Ebonite	49	.000370	2
Felt	0	.000087	1
Flannel (dry)	0	.00012	1
Glass { from		.0011	3
Glass { to	–	.0023	3
Horn	–	.000087	1
Haircloth	–	.000042	1
Ice	–	.00223	1
Ice	–	.00568	4
Leather, cow-hide	–	.00042	5
" chamois	–	.00015	5
Linen	–	.00021	5
Silk	–	.000095	5
Caen stone (building limestone)	–	.00433	2
Calc's sandstone (freestone)	–	.00211	2

1 G. Forbes. 2 H., L., & D.* 3 Various. 4 Neumann. 5 Lees-Chorlton.

TABLE 226. — Water and Salt Solutions.

Substance.	Density.	t o	k_t	Authority.
Water	–	–	.002	1
"	–	0	.00120	2
"	–	9–15	.00136	2
"	–	4	.00129	3
"	–	30	.00157	4
"	–	18	.00124	5
Solutions in water.				
$CuSO_4$	1.160	4.4	.00118	2
KCl	1.026	13	.00116	4
NaCl	33⅓%	10–18	.00267	6
H_2SO_4	1.054	20.5	.00126	5
"	1.100	20.5	.00128	5
"	1.180	21	.00130	5
$ZnSO_4$	1.134	4.5	.00118	2
"	1.136	4.5	.00115	2

1 Bottomley. 2 H. F. Weber. 3 Wachsmuth. 4 Graetz. 5 Chree. 6 Winkelmann.

TABLE 227. — Organic Liquids.

Substance.	t o	k_t ×1000	a	Authority.
Acetic acid	9–15	.472	–	1
Alcohols: amyl	9–15	.328	–	1
ethyl	9–15	.423	–	1
methyl	9–15	.495	–	1
Benzole	5	.333	–	1
Carbon disulphide	9–15	.343	–	1
Chloroform	9–15	.288	–	1
Ether	9–15	.303	–	1
Glycerine	9–15	.637	0.12	2
Oils: olive	–	.395	–	3
castor	–	.425	–	3
petroleum	13	.355	0.011	2
turpentine	13	.325	0.0067	2
Vaseline	–	.44	–	4

1 H. F. Weber. 2 Graetz. 3 Wachsmuth. 4 Lees.

TABLE 228. — Gases.

Substance.	t o	k_t ×10000	a	Authority.
Air	0	.568	.00190	1
Argon	0	.389	.00260	2
Ammonia	0	.458	.00548	1
Carbon monoxide	0	.499	–	1
" dioxide	0	.307	–	1
Ethylene	0	.395	.00445	1
Helium	0	3.39	.00318	2
Hydrogen	0	3.27	.00175	1
Methane	7–8	.647	–	1
Nitrogen	7–8	.524	–	1
Nitrous oxide	7–8	.350	.00446	1
Oxygen	7–8	.563	–	1

1 Winkelmann. 2 Schwarze.

* Herschel, Lebour, and Dunn (British Association Committee).

DIFFUSIVITIES.

The diffusivity of a substance $= h^2 = k/c\rho$, where k is the conductivity for heat, c the specific heat and ρ the density. (Kelvin.) The values are mostly for room temperatures, about 18° C.

Material.	Diffusivity.	Material.	Diffusivity.
Aluminum	0.826	Coal	0.002
Antimony	.139	Concrete (cinder)	.0032
Bismuth	.0678	" (stone)	.0058
Brass (yellow)	.339	" (light slag)	.006
Cadmium	.467	Cork (ground)	.0017
Copper	1.133	Ebonite	.0010
Gold	1.182	Glass (ordinary)	.0057
Iron (wrought, also mild steel)	0.173	Granite	.0155
Iron (cast, also 1% carbon steel)	.121	Ice	.0112
Lead	.237	Limestone	.0092
Magnesium	.883	Marble (white)	.0090
Mercury	.0327	Paraffin	.00098
Nickel	.152	Rock material (earth aver.)	.0118
Palladium	.240	" " (crustal rocks)	.0064
Platinum	.243	Sandstone	.0133
Silver	1.737	Snow (fresh)	.0033
Tin	0.407	Soil (clay or sand, slightly damp)	.005
Zinc	.402	Soil (very dry)	.0031
Air	.179	Water	.0014
Asbestos (loose)	.0035	Wood (pine, cross grain)	.00068
Brick (average fire)	.0074	" (" with ")	.0023
" (" building)	.0050		

Taken from "An Introduction to the Mathematical Theory of Heat Conduction," Ingersoll and Zobel, 1913.

TABLE 230.

HEAT OF COMBUSTION.

Heat of combustion of some common organic compounds.
Products of combustion, CO_2 or SO_2 and water, which is assumed to be in a state of vapor.

Substance.	Small calories per gram of substance.	Authority.
Acetylene	11923	Thomsen.
Alcohols: Amyl	8958	Favre and Silbermann.
Ethyl	7183	" " "
Methyl	5307	" " "
Benzene	9977	Stohmann, Kleber, and Langbein.
Coals: Bituminous	7400–8500	Various.
Anthracite	7800	Average of various.
Lignite	6900	" " "
Coke	7000	" " "
Carbon disulphide	3244	Berthelot.
Dynamite, 75%	1290	Roux and Sarran.
Gas: Coal gas	5800–11000	Mahler.
Illuminating	5200–5500	Various.
Methane	13063	Favre and Silbermann.
Naphthalene	9618–9793	Various.
Gunpowder	720–750	"
Oils: Lard	9200–9400	"
Olive	9328–9442	Stohmann.
Petroleum, Am. crude	11094	Mahler.
" " refined	11045	"
" Russian	10800	"
Woods: Beech with 12.9% H_2O	4168	Gottlieb.
Birch " 11.83 "	4207	"
Oak " 13.3 "	3990	"
Pine " 12.17 "	4422	"

HEAT VALUES AND ANALYSES OF VARIOUS TYPES OF FUEL.

(a) Coals.

Coal.		Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen	Carbon.	Nitrogen.	Oxygen.	Calories per gram.	B. T. U.'s per pound.
Lignite	Low grade	38.81	25.48	27.29	8.42	.97	7.09	37.45	.50	45.57	3526	6347
	High grade	33.38	27.44	29.62	9.56	.94	6.77	41.31	.67	40.75	3994	7189
Sub-bituminous	Low grade	22.71	34.78	36.60	5.91	.29	6.14	52.54	1.03	34.09	5115	9207
	High grade	15.54	33.03	46.06	5.37	.58	5.89	60.08	1.05	27.03	5865	10557
Bituminous	Low grade	11.44	33.93	43.92	10.71	4.94	5.39	60.06	1.02	17.88	6088	10958
	High grade	3.42	34.36	58.83	3.39	.58	5.25	77.98	1.29	11.51	7852	14134
Semi-bituminous	Low grade	2.7	14.5	75.5	7.3	.99	4.58	80.65	1.82	4.66	7845	14121
	High grade	3.26	14.57	78.20	3.97	.54	4.76	84.62	1.02	5.09	8166	14699
Semi-anthracite		2.07	9.81	78.82	9.30	1.74	3.62	80.28	1.47	3.59	7612	13702
Anthracite	Low grade	2.76	2.48	82.07	12.69	.54	2.23	79.22	.68	4.64	6987	12577
	High grade	3.33	3.27	84.28	9.12	.60	3.08	81.35	.79	5.06	7417	13351

(b) Peats (air dried).

From	Vol. Hydro-Carbon.	Fixed Carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories per gram.	B.T.U.'s per pouud.
Franklin Co., N. Y.	67.10	28.99	3.91	.15	5.93	57.17	1.48	31.36	5726	10307
Sawyer Co., Wis.	56.54	27.92	15.54	.29	4.71	51.00	1.92	26.54	4867	8761

(c) Liquid Fuels.

Fuel.	Specific Gravity at 15° C	Calories per gram.	British Thermal Units per pound.
Petroleum ether	.684–.694	12210–12220	21978–21996
Gasoline	.710–.730	11100–11400	19980–20520
Kerosene	.790–.800	11000–11200	19800–20160
Fuel oils, heavy petroleum or refinery residue	.960–.970	10200–10500	18360–18900
Alcohol, fuel or denatured with 7–9 per cent water and denaturing material	.8196–.8202	6440–6470	11592–11646

Table compiled by U. S. Geological Survey.

TABLE 232.

CHEMICAL AND PHYSICAL PROPERTIES OF FIVE DIFFERENT CLASSES OF EXPLOSIVES.

Explosive.	Specific gravity.	Number of large calories developed by 1 kilogram of the explosive.	Pressure developed in own volume after elimination of surface influence.	Unit disruptive charge by ballistic pendulum.	Rate of detonation. Cartridges 1¼ in. diam.	Duration of flame from 100 grams of explosive.	Length of flame from 100 grams.	Cartridge 1¼ in. transmitted explosion at a distance of	Products of combustion from 200 grams; gaseous, solid, and liquid, respectively.	Ignition occurred in 4% fire damp & coal dust mixture with
			Kg. per sq. cm.	Grams.	Meters per second.	Milliseconds.	Inches.	Inches.	Grams.	Grams.
(A) Forty-per-cent nitroglycerin dynamite	1.22	1221.4	8235	227*	4688	.358	24.63	12	88.4 79.7 14.5	25
(B) FFF black blasting powder	1.25	789.4	4817	374† 458*	469.4‡	925.	54.32	–	154.4 126.9 4.1‖	25
(C) Permissible explosive; nitroglycerin class	1.10	760.5	5912	301*	3008	.471	27.79	4	103.9 65.1 15.4	1000
(D) Permissible explosive; ammonium nitrate class	0.97	992.8	7300	279*	3438§	.483	25.68	1	89.8 27.5 75.5	800
(E) Permissible explosive; hydrated class	1.54	610.6	6597	434*	2479	.338	17.49	3	86.1 56.0 33.0	Over 1000

Chemical Analyses.

(A) Moisture	0.91	(D) Moisture	0.23
Nitroglycerin	39.68	Ammonium nitrate	83.10
Sodium nitrate	42.46	Sulphur	0.46
Wood pulp	13.58	Starch	2.61
Calcium carbonate	3.37	Wood pulp	1.89
(B) Moisture	0.80	Poisonous matter	2.54
Sodium nitrate	70.57	Manganese peroxide	2.64
Charcoal	17.74	Sand	6.53
Sulphur	10.89	(E) Moisture	2.34
(C) Moisture	7.89	Nitroglycerin	30.85
Nitroglycerin	24.02	Ammonium nitrate	9.94
Sodium nitrate	36.25	Sand	1.75
Wood pulp and crude fibre from grains	9.20	Coal	11.98
Starch	21.31	Clay	7.64
Calcium carbonate	0.97	Ammonium sulphate	8.96
Magnesium "	0.36	Zinc sulphate (7HO)	6.89
		Potassium sulphate	19.65

* One pound of clay tamping used. † Two pounds of clay tamping used. ‡ Rate of burning.
§ Cartridges 1⅜ in. diam. ‖ For 300 grammes.

Compiled from U. S. Geological Survey Results, — "Investigation of Explosives for use in Coal Mines, 1909."

HEAT OF

Heat of combination of elements and compounds expressed in units, such that when unit mass of the substance is units, which will be raised in temperature

Substance.	Combined with oxygen forms —	Heat units.	Combined with chlorine forms —	Heat units.	Combined with sulphur forms —	Heat units.	Authority.
Calcium	CaO	3284	$CaCl_2$	4255	CaS	2300	1
Carbon — Diamond	CO_2	7859	–	–	–	–	2
" "	CO	2141	–	–	–	–	3
" — Graphite	CO_2	7796	–	–	–	–	3
Chlorine	Cl_2O	— 254	–	–	–	–	1
Copper	Cu_2O	321	$CuCl$	520	–	–	1
"	CuO	585	$CuCl_2$	819	CuS	158	1
"	"	593	–	–	–	–	4
Hydrogen*	H_2O	34154	HCl	22000	H_2S	2250	3
"	"	34800	–	–	–	–	5
"	"	34417	–	–	–	–	6
Iron	FeO	1353	$FeCl_2$	1464	$FeSH_2O$	428	3
"	–	–	$FeCl_3$	1714	–	–	3
Iodine	I_2O_5	177	–	–	–	–	1
Lead	PbO	243	$PbCl_2$	400	PbS	98	1
Magnesium	MgO	6077	$MgCl_2$	6291	MgS	3191	1
Manganese	$MnOH_2O$	1721	$MnCl_2$	2042	$MnSH_2O_2$	841	1
Mercury	Hg_2O	105	$HgCl$	206	–	–	1
"	HgO	153	$HgCl_2$	310	HgS	84	1
Nitrogen*	N_2O	—654	–	–	–	–	1
"	NO	—1541	–	–	–	–	1
"	NO_2	— 143	–	–	–	–	1
Phosphorus (red)	P_2O_5	5272	–	–	–	–	1
" (yellow)	"	5747	–	–	–	–	7
" "	"	5964	–	–	–	–	1
Potassium	K_2O	1745	KCl	2705	K_2S	1312	8
Silver	Ag_2O	27	$AgCl$	271	Ag_2S	24	1
Sodium	Na_2O	3293	$NaCl$	4243	Na_2S	1900	8
Sulphur	SO_2	2241	–	–	–	–	1
"	"	2165	–	–	–	–	2
Tin	SnO	573	$SnCl_2$	690	–	–	4
"	–	–	$SnCl_4$	1089	–	–	7
Zinc	ZnO	1185	–	–	–	–	4
"	"	1314	$ZnCl_2$	1495	–		1

Substance.	Combined with $S+O_4$ to form —	Heat units.	Combined with $N+O_3$ to form —	Heat units.	Combined with $C+O_3$ to form —	Heat units.	Authority.
Calcium	$CaSO_4$	7997	$Ca(NO_3)_2$	5080	$CaCO_3$	6730	1
Copper	$CuSO_4$	2887	$Cu(NO_3)_2$	1304	–	–	1
Hydrogen	H_2SO_4	96450	HNO_3	41500	–	–	1
Iron	$FeSO_4$	4208	$Fe(NO_3)_2$	2134	–	–	1
Lead	$PbSO_4$	1047	$Pb(NO_3)_2$	512	$PbCO_3$	814	1
Magnesium	$MgSO_4$	12596	–	–	–	–	1
Mercury	–	–	–	–	–	–	1
Potassium	K_2SO_4	4416	KNO_3	3061	K_2CO_3	3583	1
Silver	Ag_2SO_4	776	$AgNO_3$	266	Ag_2CO_3	561	1
Sodium	Na_2SO_4	7119	$NaNO_3$	4834	Na_2CO_3	5841	1
Zinc	$ZnSO_4$	3538	–	–	–	–	1

AUTHORITIES.

1 Thomsen. 2 Berthelot. 3 Favre and Silbermann. 4 Joule. 5 Hess. 6 Average of seven different. 7 Andrews. 8 Woods.

* Combustion at constant pressure.

COMBINATION.

caused to combine with oxygen or the negative radical, the numbers indicate the amount of water, in the same from 0° to 1° C. by the addition of that heat.

Substance.	In dilute solutions.						Authority.
	Forms —	Heat units.	Forms —	Heat units.	Forms —	Heat units.	
Calcium	$CaOH_2O$	3734	$CaCl_2H_2O$	4690	$CaS + H_2O$	2457	1
Carbon — Diamond	–	–	–	–	–	–	2
" "	–	–	–	–	–	–	3
" — Graphite	–	–	–	–	–	–	3
Chlorine	–	–	–	–	–	–	1
Copper	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
"	–	–	–	–	–	–	4
Hydrogen	–	–	–	–	–	–	3
"	–	–	–	–	–	–	5
"	–	–	–	–	–	–	6
Iron	$FeO + H_2O$	1220*	$FeCl_2 + H_2O$	1785	–	–	3
"	–	–	$FeCl_3$	2280	–	–	3
Iodine	–	–	–	–	–	–	1
Lead	–	–	$PbCl_2$	368	–	–	1
Magnesium	MgO_2H_2	9050†	$MgCl_2$	7779	MgS	4784	1
Manganese	–	–	$MnCl_2$	2327	–	–	1
Mercury	–	–	–	–		–	1
"	–	–	$HgCl_2$	299		–	1
Nitrogen	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
"	–	–	–	–	–	–	1
Phosphorus (red)	–	–	–	–	–	–	1
" (yellow)	–	–	–	–	–	–	7
" "	–	–	–	–	–	–	1
Potassium	K_2O	2110*	KCl	2592	K_2S	1451	8
Silver	–	–	–	–	–	–	1
Sodium	Na_2O	3375	NaCl	4190	Na_2S	2260	8
Sulphur	–	–	–	–	–		1
"	–	–	–	–	–		2
Tin	–	–	$SnCl_2$	691	–		7
"	–	–	$SnCl_4$	1344	–	–	7
Zinc	–	–	–	–	–		4
"	–	–	$ZnCl_2$	1735	–		1

Substance.	In dilute solutions.						Authority.
	Forms —	Heat units.	Forms —	Heat units.	Forms —	Heat units.	
Calcium	–	–	$Ca(NO_3)_2$	5175	–	–	1
Copper	$CuSO_4$	3150	$Cu(NO_3)_2$	1310	–	–	1
Hydrogen	H_2SO_4	105300	HNO_3	24550	–	–	1
Iron	$FeSO_4$	4210	$Fe(NO_3)_3$	2134	–	–	1
Lead	–	–	$Pb(NO_3)_2$	475	–	–	1
Magnesium	$MgSO_4$	13420	$Mg(NO_3)_2$	8595	–	–	1
Mercury	–	–	$Hg(NO_3)_2$	335	–	–	1
Potassium	K_2SO_4	4324	KNO_3	2860	–	–	1
Silver	Ag_2SO_4	753	$AgNO_3$	216	-	–	1
Sodium	Na_2SO_4	7160	$NaNO_3$	4620	Na_2CO_3	5995	1
Zinc	$ZnSO_4$	3820	$Zn(NO_3)_2$	2035		–	1

AUTHORITIES.

1 Thomsen. 2 Berthelot. 3 Favre and Silbermann. 4 Joule. 5 Hess. 6 Average of seven different. 7 Andrews. 8 Woods.

* Thomsen. † Total heat from elements.

TABLE 234.

LATENT HEAT OF VAPORIZATION.

The temperature of vaporization in degrees Centigrade is indicated by T; the latent heat in large calories per kilogram or in small calories or therms per gram by H; the total heat from 0° C, in the same units by H'. The pressure is that due to the vapor at the temperature T.

Substance.	Formula.	T	H	H'	Authority.
Acetic acid	$C_2H_4O_2$	118°	84.9		Ogier.
Air	–	–	50.97	–	Fenner-Richtmyer.
Alcohol: Amyl	$C_5H_{12}O$	131	120		Schall.
Ethyl	C_2H_6O	78.1	205	255	Wirtz.
"	"	0	236	236	Regnault.
"	"	50	–	264	"
"	"	100	–	267	"
"	"	150	–	285	"
Methyl	CH_4O	64.5	2.67	307	Wirtz.
"	"	0	289	289	Ramsay and Young.
"	"	50	–	274	" " "
"	"	100	–	246	" " "
"	"	150		206	" " "
"	"	200	–	152	" " "
"	"	238.5	–	44.2	" " "
Ammonia	NH_3	7.8	294.2	–	Regnault.
"	"	11	291.3	–	"
"	"	16	297.4		"
"	"	17	296.5		"
Benzene	C_6H_6	80.1	92.9	127.9	Wirtz.
Bromine	Br	61	45.6	–	Andrews.
Carbon dioxide, solid	CO_2		–	138.7	Favre.
" " liquid	"	—25	72.23	–	Cailletet and Mathias.
" " "	"	0	57.48	–	" " "
" " "	"	12.35	44.97	–	Mathias.
" " "	"	22.04	31.8	–	"
" " "	"	29.85	14.4	–	"
" " "	"	30.82	3.72	–	"
" disulphide	CS_2	46.1	83.8	94.8	Wirtz.
" "	"	0	90	90	Regnault.
" "	"	100	–	100.5	"
" "	"	140		102.4	"
Chloroform	$CHCl_3$	60.9	58.5	72.8	Wirtz.
Ether	$C_4H_{10}O$	34.5	88.4	107	"
"	"	34.9	90.5	–	Andrews.
"	"	0	94	94	Regnault.
"	"	50	–	115.1	"
"	"	120	–	140	"
Iodine	I	–	23.95	–	Favre and Silbermann.
Mercury	Hg	357	65	–	Mean.
Nitrogen	N	—195.6	47.65	–	Alt.
Oxygen	O	—182.9	50.97	–	"
Sulphur dioxide	SO_2	0	91.2	–	Cailletet and Mathias.
" "	"	30	80.5	–	" " "
" "	"	65	68.4	–	" " "
Turpentine	$C_{10}H_{10}$	159.3	74.04	–	Brix.
Water	H_2O	100	535.9	–	Andrews.
"	"	100	–	637	Regnault.

LATENT HEAT OF VAPORIZATION.*

Substance, formula, and temperature.	l = total heat from fluid at 0° to vapor at t°. r = latent heat at t°.	Authority.
Acetone, C_3H_6O, − 3° to 147°.	$l = 140.5 + 0.36644\,t - 0.000516\,t^2$ $l = 139.9 + 0.23356\,t + 0.00055358\,t^2$ $r = 139.9 - 0.27287\,t + 0.0001571\,t^2$	Regnault. Winkelmann. "
Benzol, C_6H_6, 7° to 215°.	$l = 109.0 + 0.24429\,t - 0.0001315\,t^2$	Regnault.
Carbon dioxide, CO_2, − 25° to 31°.	$r^2 = 118.485\,(31 - t) - 0.4707\,(31 - t^2)$	Cailletet and Mathias.
Carbon disulphide, CS_2, − 6° to 143°.	$l = 90.0 + 0.14601\,t - 0.000412\,t^2$ $l = 89.5 + 0.16993\,t - 0.0010161\,t^2 + 0.000003424\,t^3$ $r = 89.5 - 0.06530\,t - 0.0010976\,t^2 + 0.000003424\,t^3$	Regnault. Winkelmann. "
Carbon tetrachloride, CCl_4, 8° to 163°.	$l = 52.0 + 0.14625\,t - 0.000172\,t^2$ $l = 51.9 + 0.17867\,t - 0.0009599\,t^2 + 0.000003733\,t^3$ $r = 51.9 - 0.01931\,t - 0.0010505\,t^2 + 0.000003733\,t^3$	Regnault. Winkelmann. "
Chloroform, $CHCl_3$, − 5° to 159°.	$l = 67.0 + 0.1375\,t$ $l = 67.0 + 0.14716\,t - 0.0000937\,t^2$ $r = 67.0 - 0.08519\,t - 0.0001444\,t^2$	Regnault. Winkelmann. "
Nitrogen, N.	$r = 68.85 - 0.2736\,T$	Alt.
Nitrous oxide, N_2O, − 20° to 36°.	$r^2 = 131.75\,(36.4 - t) - 0.928\,(36.4 - t)^2$	Cailletet and Mathias.
Oxygen, O.	$r = 60.67 - 0.2080\,T$	Alt.
Sulphur dioxide, SO_2, 0° to 60°.	$r = 91.87 - 0.3842\,t - 0.000340\,t^2$	Mathias.
Water, H_2O.	$r = 94.210\,(365 - t)^{0.31249}$, 30° — 100° $r = 538.46 - 0.6422\,(t - 100) - 0.000833\,(t - 100)^2$, 100°–180° $r = 539.66 - 0.718\,(t - 100)$, 120°–180°	Henning. "

* Quoted from Landolt & Börnstein's "Phys. Chem. Tab."

TABLE 235.

LATENT HEAT OF FUSION.

This table contains the latent heat of fusion of a number of solid substances in large calories per kilogram or small calories or therms per gram. It has been compiled principally from Landolt and Börnstein's tables. *C* indicates the composition, *T* the temperature Centigrade, and *H* the latent heat.

Substance.	*C*	*T*	*H*	Authority.
Alloys: 30.5Pb + 69.5Sn	$PbSn_4$	183	17.	Spring.
36.9Pb + 63.1Sn	$PbSn_3$	179	15.5	"
63.7Pb + 36.3Sn	PbSn	177.5	11.6	"
77.8Pb + 22.2Sn	Pb_2Sn	176.5	9.54	"
Britannia metal, 9Sn + 1Pb	–	236	28.0*	Ledebur.
Rose's alloy, 24Pb + 27.3Sn + 48.7Bi	–	98.8	6.85	Mazzotto.
Wood's alloy {25.8Pb + 14.7Sn + 52.4Bi + 7Cd}	–	75.5	8.40	"
Aluminum	Al	658.	76.8	Glaser.
Ammonia	NH_3	—75.	108.	Massol.
Benzole	C_6H_6	5.4	30.6	Mean.
Bromine	Br	—7.3	16.2	Regnault.
Bismuth	Bi	268	12.64	Person.
Cadmium	Cd	320.7	13.66	"
Calcium chloride	$CaCl_2 + 6H_2O$	28.5	40.7	"
Copper	Cu	1083	42.	Mean.
Iron, Gray cast	–	–	23.	Gruner.
" White "	–	–	33.	"
" Slag	–	–	50.	"
Iodine	I	–	11.71	Favre and Silbermann.
Ice	H_2O	0	79.63	Dickinson, Harper, Osborne.†
"	"	0	79.59	Smith.‡
" (from sea-water)	{H_2O + 3.535 of solids}	—8.7	54.0	Petterson.
Lead	Pb	327	5.36	Mean.
Mercury	Hg	—39	2.82	Person.
Naphthalene	$C_{10}H_8$	79.87	35.62	Pickering.
Nickel	Ni	1435	4.64	Pionchon.
Palladium	Pd	1545	36.3	Violle.
Phosphorus	P	44.2	4.97	Petterson.
Platinum	Pt	1755	27.2	Violle.
Potassium	K	62	15.7	Joannis.
Potassium nitrate	KNO_3	333.5	48.9	Person.
Phenol	C_6H_6O	25.37	24.93	Petterson.
Paraffin	–	52.40	35.10	Batelli.
Silver	Ag	961	21.07	Person.
Sodium	Na	97	31.7	Joannis.
" nitrate	$NaNO_3$	305.8	64.87	"
" phosphate	{Na_2HPO_4 + $12H_2O$}	36.1	66.8	"
Spermaceti	–	43.9	36.98	Batelli.
Sulphur	S	115	9.37	Person.
Tin	Sn	232	14.0	Mean.
Wax (bees)	–	61.8	42.3	"
Zinc	Zn	419	28.13	"

* Total heat from 0° C.
† U. S. Bureau of Standards, 1913, in terms of 15° calorie.
‡ 1903, based on electrical measurements, assuming mechanical equivalent = 4.187, and in terms of the value of the international volt in use after 1911.

TABLE 236.

MELTING-POINTS OF THE CHEMICAL ELEMENTS.

The metals in heavier type are often used as standards.

The melting-points are reduced as far as possible to a common temperature scale which is the one used by the United States Bureau of Standards in certifying pyrometers. This scale is defined in terms of Wien's law with C_2 taken as 14500, and on which the melting-point of platinum is 1755° C (Nernst and Wartenburg, 1751; Waidner and Burgess, 1753; Holborn and Valentiner, 1770; see C. R. 148, p. 1177, 1909). Above 1100° C, the temperatures are expressed to the nearest 5° C. Temperatures above the platinum point may be uncertain by over 50° C.

Element.	Melting-point.	Remarks.
Aluminum	658 ± 1	Most samples give 657 or less (Burgess).
Antimony	630 ± 1	"Kahlbaum" purity.
Argon	— 188	Ramsay-Travers.
Arsenic	500	
Barium	850	(Guntz.)
Beryllium	<Ag	
Bismuth	270	Adjusted.
Boron	{ > 2000 } { < 2500 }	Weintraub.
Bromine	— 7.3	
Cadmium	321	Range: 320.7–320.9.
Cæsium	26	Range: 26.37–25.3
Calcium	805	Adjusted.
Chlorine	— 102	(Olszewski.)
Carbon	(>3500)	Sublimes.
Cerium	645	
Chromium	>1520	Burgess-Waltenberg
Cobalt	1478	Burgess-Waltenberg
Copper	1083 ± 3	Mean, Holborn-Day, Day-Clement.
Erbium		
Fluorine	— 223	(Moissan - Dewar.)
Gallium	30.1	
Germanium	< Ag	
Gold	1063 ± 3	Adjusted.
Hydrogen	— 259	
Indium	155	(Thiel.)
Iodine	114	Range: 112–115.
Iridium	2290	Mendenhall Ingersoll.
Iron	1530	Burgess-Waltenberg.
Krypton	— 169	(Ramsay).
Lanthanum	810	(Muthmann-Weiss.)
Lead	327 ± 0.5	
Lithium	186	(Kahlbaum.)
Magnesium	651	(Grube) in clay crucibles, 635.
Manganese	1260	Burgess-Waltenberg
Mercury	— 38.7	
Molybdenum	2535	Mendenhall-Forsythe
Neodymium	840	(Muthmann-Weiss.)
Neon	— 252	
Nickel	1452	Day, Sosman, Burgess, Waltenberg.
Niobium	1950	v. Bolton.
Nitrogen	— 211	(Fischer-Alt.)
Osmium	About 2700	(Waidner - Burgess, unpublished.)
Oxygen	— 230 ?	
Palladium	1545 ± 15	(Waidner-Burgess, Nernst-Wartenburg.)
Phosphorus	44.2	
Platinum	1755 ± 20	See Note.
Potassium	62.3	
Præsodymium	940	(Muthmann-Weiss.)
Rhodium	1910	(Mendenhall-Ingersoll.)
Rubidium	38.5	
Ruthenium	1900 ?	
Samarium	1300–1400	(Muthmann-Weiss.)
Selenium	217	Saunders.
Silicon	1420	Adjusted.
Silver	961 ± 1	Adjusted.
Sodium	97	
Strontium		Between Ca and Ba?
Sulphur	113.5–119.5	Various forms. See Landolt-Börnstein.
Tantalum	2800	Adjusted from Waidner-Burgess = 2910.
Tellurium	451	Adjusted.
Thallium	302	
Thorium	>1700<Pt	v. Wartenburg.
Tin	$231.9 \pm .2$	
Titanium	1795	Burgess-Waltenberg.
Tungsten	2950	Mean, Waidner-Burgess and Wartenburg.
Uranium	Near Mo	Moissan.
Vanadium	1720	Burgess-Waltenberg.
Xenon	— 140	Ramsay.
Zinc	419 ± 0.5	
Zirconium	> Si	Troost.

TABLE 237.

BOILING-POINTS OF THE CHEMICAL ELEMENTS.

Element.	Range.	Boiling-point.	Observer; Remarks.
	°	°	
Aluminum	–	1800.	Greenwood, Ch. News, 100, 1909.
Antimony		1440.	" " " " "
Argon	–	—186.1	Ramsay-Travers, Z. Phys. Ch. 38, 1901.
Arsenic	449–450	–	Gray, sublimes, Conechy.
"	–	>360.	Black, sublimes, Engel, C. R. 96, 1883.
"	280–310	–	Yellow, sublimes.
Barium	–	–	Boils in vacuo, Guntz, 1903.
Bismuth	1420–1435	1430.	Barus, 1894; Greenwood, l. c.
Boron	–	–	Volatilizes without melting in electric arc.
Bromine	59–63	61.1	Thorpe, 1880; van der Plaats, 1886.
Cadmium	–	778.	Berthelot, 1902.
Cæsium	–	670.	Ruff-Johannsen.
Carbon	–	3600.	Computed, Violle, C. R. 120, 1895.
"	–	–	Volatilizes without melting in electric oven, Moisson.
Chlorine	–	—33.6	Regnault, 1863.
Chromium	–	2200.	Greenwood, Ch. News, 100, 1909.
Copper	2100–2310	2310.	" l. c.
Fluorine	–	—187.	Moisson-Dewar, C. R. 136, 1903.
Helium	–	—267.	Computed, Tracers Ch. News, 86, 1902.
Hydrogen	—252.5–252.8	—252.6	Mean.
Iodine	–	>200.	
Iron		2450.	Greenwood, l. c.
Krypton	–	—151.7	Ramsay, Ch. News, 87, 1903.
Lead	–	1525.	Greenwood, l. c.
Lithium	–	1400.	Ruff-Johannsen, Ch. Ber. 38, 1905.
Magnesium	–	1120.	Greenwood, l. c.
Manganese	–	1900.	" "
Mercury	–	357.	Crafts; Regnault.
Neon	–	—239.	Dewar, 1901.
Nitrogen	—195.7–194.4	—195.	Mean.
Oxygen	—182.5–182.9	—182.7	"
Ozone	–	—119.	Troost, C. R. 126, 1898.
Phosphorus	287–290	288.	
Potassium	667–757	712.	Perman; Ruff-Johannsen.
Rubidium	–	696.	Ruff-Johannsen.
Selenium	664–694	690.	
Silver	–	1955.	Greenwood, l. c.
Sodium	742–757	750.	Perman; Ruff-Johannsen.
Sulphur	444.7–445	444.7	Mean.
Tellurium	–	1390.	Deville-Troost, C. R. 91, 1880.
Thallium	–	1280.	v. Wartenberg, 25 Anorg. Ch. 56, 1908.
Tin	–	2270.	Greenwood, l. c.
Xenon	–	—109.1	Ramsay, Z. Phys. Ch. 44, 1903.
Zinc	916–942	930.	

DENSITIES AND MELTING AND BOILING POINTS. INORGANIC COMPOUNDS.

Substance.	Chemical Formula.	Density about 20° C.	Melting-point C.	Authority.	Boiling-point C.	Pressure mm.	Authority.
Aluminum chloride	$AlCl_3$	–	190.	1	183°	752	1
" nitrate	$Al(NO_3)_3+9H_2O$	–	72.8	2	–	–	–
Aluminum oxide	Al_2O_3	4.00	2020	11	–	–	–
Ammonia	NH_3	–	−75.	3	−33.5	760	7
Ammonium nitrate	NH_4NO_3	1.72	165.	–	–		–
" sulphate	$(NH_4)_2SO_4$	1.77	140.	4	–		–
" phosphite	$NH_4H_2PO_3$	–	123.	5	–	–	–
Antimony trichloride	$SbCl_3$	3.06	73.	–	223.	760	–
" pentachloride	$SbCl_5$	2.35	3.	11	102.	68	14
Arsenic trichloride	$AsCl_3$	2.20	−18.	8	130.2	760	23
Arsenietted hydrogen	AsH_3	–	−113.5	6	−54.8	"	6
Barium chloride	$BaCl_2.2H_2O$	3.10	113.	9	–		–
" nitrate	$Ba(NO_3)_2$	3.24	575.	24	–	–	–
" perchlorate	$Ba(ClO_4)_2$	–	505.	10	–	–	–
Bismuth trichloride	$BiCl_3$	4.56	232.5	–	440.	760	–
Boric acid	H_3BO_3	1.46	185.	–	–	–	–
" anhydride	B_2O_3	1.79	577.	–	–	–	–
Borax (sodium borate)	$Na_2B_4O_7$	1.69	561+	9		–	–
Cadmium chloride	$CdCl_2$	4.05	560.	25	900.±	–	9
" nitrate	$Cd(NO_3)_2+4H_2O$	2.45	59.5	2	132.	760	4
Calcium chloride	$CaCl_2$	2.26	774.	–	–	–	–
" "	$CaCl_2+6H_2O$	1.68	29.6	–	–	–	–
" nitrate	$Ca(NO_3)_2$	2.36	499.	24	–	–	–
" "	$Ca(NO_3)_2+4H_2O$	1.82	42.3	26	–	–	–
Carbon tetrachloride	CCl_4	1.59	−24.	22	76.7	760	23
" trichloride	C_2Cl_6	1.63	184.	–	–	–	–
" monoxide	CO	–	−207.	6	−190.	760	6
" dioxide	CO_2	–	−57.	3	−80.	subl.	–
" disulphide	CS_2	1.26	−110.	13	46.2	760	–
Chloric acid	$HClO_4+H_2O$	1.81	50.	15	–	–	–
Chlorine dioxide	ClO_2	–	−76.	3	9.9	731	21
Chrome alum	$KCr(SO_4)_2+12H_2O$	1.83	89.	16	–	–	–
" nitrate	$Cr_2(NO_3)_6+18H_2O$	–	37.	2	170.	760	2
Cobalt sulphate	$CoSO_4$	3.53	97.	16	–	–	–
Cupric chloride	$CuCl_2$	3.05	498.	9	–	–	–
Cuprous "	Cu_2Cl_2	3.7	421.	–	1000.±	760	9
Cupric nitrate	$Cu(NO_3)_2+3H_2O$	2.05	114.5	2	170.	760	2
Hydrobromic acid	HBr	–	−86.7	3	−68.7	"	–
Hydrochloric "	HCl	–	−111.3	17	−83.1	755	17
Hydrofluoric "	HFl	.99	−92.3	6	−36.7	"	17
Hydriodic "	HI	–	−51.3	17	−35.7	760	–
Hydrogen peroxide	H_2O_2	1.5	−2.	18	80.2	47	20
" phosphide	PH_3	–	−132.5	6	–	–	–
" sulphide	H_2S	–	−86.	3	−62.	–	–
Iron chloride	$FeCl_3$	2.80	301.	–	–	–	–
" nitrate	$Fe(NO_3)_3+9H_2O$	1.68	47.2	2	–	–	–
" sulphate	$FeSO_4+7H_2O$	1.90	64.	16	–	–	–
Lead chloride	$PbCl_2$	5.8	500.	9	900.±	760	–
" metaphosphate	$Pb(PO_3)_2$	–	800.	9	–	–	–
Magnesium chloride	$MgCl_2$	2.18	708.	9	–	–	–
" nitrate	$Mg(NO_3)_2+6H_2O$	1.46	90.	2	143.	760	2
" sulphate	$MgSO_4+5H_2O$	1.68	150.	16	–	–	–
Manganese chloride	$MnCl_2+4H_2O$	2.01	87.5	19	106.	760	19
" nitrate	$Mn(NO_3)_2+6H_2O$	1.82	26.	2	129.	"	2
" sulphate	$MnSO_4+5H_2O$	2.09	54.	16	–	–	–
Mercurous chloride	Hg_2Cl_2	7.10	450±		–	–	–
Mercuric chloride	$HgCl_2$	5.42	282.		305.	–	–

1, Friedel and Crafts; 2, Ordway; 3, Faraday; 4, Marchand; 5, Amat; 6, Olszweski; 7, Gibbs; 8, Baskerville; 9, Carnelly; 10, Carnelly and O'Shea; 11, Ruff; 13, Wroblewski and Olszewski; 14, Anschütz; 15, Roscoe; 16, Tilden; 17, Ladenburg; 18, Staedel; 19, Clarke, "Const. of Nature"; 20, Bruhl; 21, Schacherl; 22, Tammaa; 23, Thorpe; 24, Ramsay; 25, Lorenz; 26, Morgan.

DENSITIES AND MELTING- AND BOILING-POINTS.
INORGANIC COMPOUNDS.

Substance.	Chemical Formula.	Density about 20° C.	Melting-point C.	Authority.	Boiling-point C.	Pressure mm.	Authority.
Nickel carbonyl	NiC_4O_4	1.32	−25.	1	43°	760	–
" nitrate	$Ni(NO_3)_2 + 6H_2O$	2.05	56.7	2	136.7	"	2
" oxide	NiO	6.69	–		–	–	–
" sulphate	$NiSO_4 + 7H_2O$	1.98	99.	3	–	–	–
Nitric acid	HNO_3	1.52	−42.	4	86.	760	16
" anhydride . . .	N_2O_5	1.64	30.	5	48.	"	9
" oxide*	NO	–	−155.	–	−153.	"	6
" peroxide	N_2O_4	–	−10.1	8	24.	760	–
Nitrous anhydride . . .	N_2O_3	–	−82.	7	0.±	"	–
" oxide	N_2O	–	−102.4	8	−89.8	"	8
Phosphoric acid (ortho) .	H_3PO_4	1.88	40.±	–	–	–	–
Phosphorous acid . . .	H_3PO_3	1.65	72.	–	.	–	–
Phosphorus trichloride .	PCl_3	1.61	−111.8	10	76.	760	19
" oxychloride .	$POCl_3$	1.68	+1.3	–	108.	"	–
" disulphide . .	P_3S_3	–	297.	12	–	"	–
" pentasulphide	P_2S_5	–	275.	13	522.	"	–
" sesquisulphide	P_4S_3	2.10	168.	–	400.	"	–
" trisulphide .	P_2S_3	–	290.±	14	490.	"	25
Potassium carbonate . .	K_2CO_3	2.29	840.±	–	–	–	–
" chlorate . .	$KClO_3$	2.34	372.	15	–	–	–
" chromate . .	K_2CrO_4	2.72	975.	17		–	–
" cyanide . . .	KCN	1.52	–	–	–	–	–
" perchlorate .	$KClO_4$	2.52	610.	15	–	–	–
" chloride . .	KCl	1.99	801.	–	–		–
" nitrate . . .	KNO_3	2.10	341.	–	–	–	–
" acid phosphate	KH_2PO_4	2.34	96.	3	–	–	–
" acid sulphate .	$KHSO_4$	2.35	205.	–	–	–	–
Silver chloride , . . .	$AgCl$	5.56	451.	15	–	–	–
" nitrate	$AgNO_3$	4.35	208.7	–	–	–	–
" perchlorate . . .	$AgClO_4$	–	486.	18	–	–	–
" phosphate . . .	Ag_3PO_4	6.37	849.	15	–	–	–
" metaphosphate . .	$AgPO_3$	–	482.	15	–	–	–
" sulphate	Ag_2SO_4	5.45	655.±	–	–	–	–
Sodium chloride . . .	$NaCl$	2.17	800.	11	–	–	–
" hydroxide . . .	$NaOH$	2.1	318.	27	–	–	–
" nitrate	$NaNO_3$	2.26	315.	–	–	–	–
" chlorate . . .	$NaClO_3$	2.48	248.	28		–	–
" perchlorate . .	$NaClO_4$	–	482.	18	–	–	–
" carbonate . . .	Na_2CO_3	2.48	852.		–	–	–
" " . . .	$Na_2CO_3 + 10H_2O$	1.46	34.	3	–	–	–
" phosphate . . .	$Na_2HPO_4 + 12H_2O$	1.54	38.	–	–	–	–
" metaphosphate .	$NaPO_3$	2.48	617.	15	–	–	–
" pyrophosphate .	$Na_4P_2O_7$	2.45	970.	30	–	–	–
" phosphite . . .	$(H_2NaPO_3)_2 + 5H_2O$	–	42.	20	–	–	–
" sulphate . . .	Na_2SO_4	2.67	884.	11	–	–	–
" " . . .	$Na_2SO_4 + 10H_2O$	1.46	32.38	17	–	–	–
" hyposulphite . .	$Na_2S_2O_3 + 5H_2O$	1.73	48.16	–	–	–	–
Sulphur dioxide	SO_2	–	−76.	–	−10.	760	–
Sulphuric acid	H_2SO_4	1.83	10.4	21	338.	"	22
" "	$12H_2SO_4 + H_2O$	–	−0.5	22	–		–
" "	$H_2SO_4 + H_2O$	–	8.5	–	–	–	–
" " (pyro) . .	$H_2S_2O_7$	–	35.	22	–	–	–
Sulphur trioxide	SO_3	1.91	15.	–	46.2	760	–
Tin, stannic chloride . .	$SnCl_4$	2.28	−33.	23	114.	"	19
" stannous " . .	$SnCl_2$	–	250.	24	605.	"	–
Zinc chloride	$ZnCl_2$	2.91	365.	29	710.	"	–
" "	$ZnCl_2 + 3H_2O$	–	6.5	26	–	–	–
" nitrate	$Zn(NO_3)_2 + 6H_2O$	2.06	36.4	3	131.	760	2
" sulphate	$ZnSO_4 + 7H_2O$	2.02	50.	3	–	–	–

1, Mond, Langer, Quincke; 2, Ordway; 3, Tilden; 4, Erdmann; 5, R. Weber; 6, Olszewski; 7, Birhaus; 8, Ramsay; 9, Deville; 10, Wroblewski; 11, Day, Sosman, White; 12, Ramme; 13, Meyer; 14, Lemoine; 15, Carnelly; 16, Mitscherlich; 17, LeChatelier; 18, Carnelly, O'Shea; 19, Thorpe; 20, Amat; 21, Mendelejeff; 22, Marignac; 23, Besson; 24, Clarke, "Const. of Nature"; 25, Isambert; 26, Mylius; 27, Hevesy; 28, Retgers; 29, Grünauer; 30, Richards and others.

* Under pressure 138 mm. mercury.

TABLE 239. — Effect of Pressure on Melting-Point.

Substance.	Melting-point at 1 kg/sq. cm.	Highest experimental pressure: kg/sq. cm.	dt/dp at 1 kg/sq. cm.	Δ t. (observed) for 1000 kg/sq. cm.	Reference.
Hg	−38.85	12000	0.00511	5.1*	1
K	59.7	2800	.0136	13.8	2
Na	97.4	2800	.0082	8.2	2
Sn	231.9	2000	.00317	3.17	3
Bi	270.9	2000	−0.00344	−3.44	3
Cd	320.9	2000	0.00609	6.09	3
Pb	327.4	2000	.00777	7.77	3

* Δ t (observed) for 10000 kg/sq. cm. is 50.8°.

References. — 1. P. W. Bridgman, "Proc. Am. Acad." 47, pp. 391–96, 416–19, 1911.
2. G. Tammann, "Kristallisieren und Schmelzen," Leipzig, 1903, pp. 98–99.
3. J. Johnston and L. H. Adams, "Am. J. Sci." 31, p. 516, 1911.

A large number of organic substances, selected on account of their low melting-points, have also been investigated: by Tammann, *loc. cit.*; G. A. Hulett, "Z. Physik. Chem." 28, p. 629, 1899; F. Körber, *ibid.*, 82, p. 45, 1913; E. A. Block, *ibid.*, 82, p. 403, 1913. The results for water are given in the following table.

TABLE 240. — Effect of Pressure on the Freezing-Point of Water (Bridgman*).

Pressure†: kg/sq. cm.	Freezing-point.	Phases in Equilibrium.
1	0.0	Ice I — liquid.
1000	−8.8	"
2000	−20.15	"
2115	−22.0	Ice I — ice III — liquid (triple point).
3000	−18.40	Ice III — liquid.
3530	−17.0	Ice III — ice V — liquid (triple point).
4000	−13.7	Ice V — liquid.
6000	−1.6	"
6380	+0.16	Ice V — ice VI — liquid (triple point).
8000	12.8	Ice VI — liquid.
12000	37.9	"
16000	57.2	"
20000	73.6	"

* P. W. Bridgman, "Proc. Am. Acad." p. 47, 441–558, 1912.
† 1 atm. = 1.033 kg/sq. cm.

TABLE 241. — Melting-point of Mixtures.

Metals.	Melting-points, C°. Percentage of metal in second column. 0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100 %	Reference.
Pb. So.	326	295	276	262	240	220	190	185	200	216	232	1
Bi.	322	290	-	-	179	145	126	168	205	-	268	7
Te.	322	710	790	880	917	760	600	480	410	425	446	8
Ag.	328	460	545	590	620	650	705	775	840	905	959	9
Na.	-	360	420	400	370	330	290	250	200	130	96	13
Cu.	326	870	920	925	945	950	955	985	1005	1020	1084	2
Sb.	326	250	275	330	395	440	490	525	560	600	632	16
Al. Sb.	650	750	840	925	945	950	970	1000	1040	1010	632	17
Cu.	650	630	600	560	540	580	610	755	930	1055	1084	18
Au.	655	675	740	800	855	915	970	1025	1055	675	1062	10
Ag.	650	625	615	600	590	580	575	570	650	750	954	17
Zn.	654	640	620	600	580	560	530	510	475	425	419	11
Fe.	653	860	1015	1110	1145	1145	1220	1315	1425	1500	1515	3
Sn.	650	645	635	625	620	605	590	570	560	540	232	17
Sb. Bi.	632	610	590	575	555	540	520	470	405	330	268	16
Ag.	630	595	570	545	520	500	505	545	680	850	959	9
Sn.	622	600	570	525	480	430	395	350	310	255	232	19
Zn.	632	555	510	540	570	565	540	525	510	470	419	17
Ni. So.	1455	1380	1290	1200	1235	1290	1305	1230	1060	800	232	17
Na. Bi.	96	425	520	590	645	690	720	730	715	570	268	13
Cd.	96	125	185	245	285	325	330	340	360	390	322	13
Cd. Ag.	322	420	520	610	700	760	805	850	895	940	954	17
Tl.	321	300	285	270	262	258	245	230	210	235	302	14
Zn.	322	280	270	295	313	327	340	355	370	390	419	11
Au. Cu.	1063	910	890	895	905	925	975	1000	1025	1060	1084	4
Ag.	1064	1062	1061	1058	1054	1049	1039	1025	1006	982	963	5
Pt.	1075	1125	1190	1250	1320	1380	1455	1530	1610	1685	1775	20
K. Na.	62	17.5	—10	—3.5	5	11	26	41	58	77	97.5	15
Hg.	-	-	-	-	-	90	110	135	162	265	-	13
Tl.	62.5	133	165	188	205	215	220	240	280	305	301	14
Cu. Ni.	1080	1180	1240	1290	1320	1335	1380	1410	1430	1440	1455	17
Ag.	1082	1035	990	945	910	870	830	788	814	875	960	9
Sn.	1084	1005	890	755	725	680	630	580	530	440	232	12
Zn.	1084	1040	995	930	900	880	820	780	700	580	419	6
Ag. Zn.	959	850	755	705	690	660	630	610	570	505	419	11
Sn.	959	870	750	630	550	495	450	420	375	300	232	9
Na. Hg.	96.5	90	80	70	60	45	22	55	95	215	-	13

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20 Erhard and Schertel, Jahrb. Berg-u. Hüttenw. Sachsen. 1879, 17.

TABLE 242. — Alloy of Lead, Tin, and Bismuth.

	Per cent.									
Lead	32.0	25.8	25.0	43.0	33.3	10.7	50.0	35.8	20.0	70.9
Tin	15.5	19.8	15.0	14.0	33.3	23.1	33.0	52.1	60.0	9.1
Bismuth	52.5	54.4	60.0	43.0	33.3	66.2	17.0	12.1	20.0	20.0
Solidification at	96°	101°	125°	128°	145°	148°	161°	181°	182°	234°

Charpy, Soc. d'Encours, Paris, 1901.

TABLE 243. — Low Melting-point Alloy.

	Per cent.						
Cadmium	10.8	10.2	14.8	13.1	6.2	7.1	6.7
Tin	14.2	14.3	7.0	13.8	9.4	-	-
Lead	24.9	25.1	26.0	24.3	34.4	39.7	43.4
Bismuth	50.1	50.4	52.2	48.8	50.0	53.2	49.9
Solidification at	65.5°	67.5°	68.5°	68.5°	76.5°	89.5°	95°

Drewitz, Diss. Rostock, 1902.

All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 244.

DENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

N.B. — The data in this table refer only to normal compounds.

Substance.	Formula	Temp. ° C.	Density.	Melting-point	Boiling-point.	Authority.
(a) Paraffin Series: C_nH_{2n+2}.						
Methane*	CH_4	—164.	0.415	—184	—165.	Olszewski, Young.
Ethane†	C_2H_6	0	.446	—171.4	—93.	Ladenburg, "
Propane	C_3H_8	0	.536	—195	—45.	Young, Hainlen.
Butane	C_4H_{10}	0	.60	-	1.	Butlerow, Young.
Pentane	C_5H_{12}	0	.647	-	36.3	Thorpe, Young.
Hexane	C_6H_{14}	17.	.663	-	69.	Schorlemmer.
Heptane	C_7H_{16}	0	.701	-	98.4	Thorpe, Young.
Octane	C_8H_{18}	0	.719		125.5	" "
Nonane	C_9H_{20}	0	.733	—51.	150.	Krafft.
Decane	$C_{10}H_{22}$	0	.745	—31.	173.	"
Undecane	$C_{11}H_{24}$	0	.756	—26.	195.	"
Dodecane	$C_{12}H_{26}$	0	.765	—12.	214.	"
Tridecane	$C_{13}H_{28}$	0	.771	—6.	234.	"
Tetradecane	$C_{14}H_{30}$	4.	.775	5.	252.	"
Pentadecane	$C_{15}H_{32}$	10.	.776	10.	270.	"
Hexadecane	$C_{16}H_{34}$	18.	.775	18.	287.	"
Heptadecane	$C_{17}H_{36}$	22.	.777	22.	303.	"
Octadecane	$C_{18}H_{38}$	28.	.777	28.	317.	"
Nonadecane	$C_{19}H_{40}$	32.	.777	32.	330.	"
Eicosane	$C_{20}H_{42}$	37.	.778	37.	121.§	"
Heneicosane	$C_{21}H_{44}$	40.	.778	40.	129.§	"
Docosane	$C_{22}H_{46}$	44.	.778	44.	136.5§	"
Tricosane	$C_{23}H_{48}$	48.	.779	48.	142.5§	"
Tetracosane	$C_{24}H_{50}$	51.	.779	51.	243.‡	"
Heptacosane	$C_{27}H_{56}$	60.	.780	60.	172.§	"
Pentriacontane	$C_{31}H_{64}$	68.	.781	68.	199.§	"
Dicetyl	$C_{32}H_{66}$	70.	.781	70.	205.§	"
Penta-tria-contane	$C_{35}H_{72}$	75.	.782	75.	331.‡	"
(b) Olefines, or the Ethylene Series: C_nH_{2n}.						
Ethylene	C_2H_4	-	0.610	—169.	—103.	Wroblewski or Olszewski.
Propylene	C_3H_6	-	-	-	—50.2	Ladenburg, Krügel.
Butylene	C_4H_8	—13.5	.635	-	1.	Sieben.
Amylone	C_5H_{10}	-	-	-	36.	Wagner or Saytzeff.
Hexylene	C_6H_{12}	0	.76	-	69.	Wreden or Znatowicz.
Heptylene	C_7H_{14}	19.5	.703	-	96.–99.	Morgan or Schorlemmer.
Octylene	C_8H_{16}	17.	.722	-	122.–123.	Möslinger.
Nonylene	C_9H_{18}	20.	.767	-	140.–142.	Beilstein, "Org. Chem."
Decylene	$C_{10}H_{20}$	-	-	-	175.	" " "
Undecylene	$C_{11}H_{22}$	20.	.773	-	196.–197.	" " "
Dodecylene	$C_{12}H_{24}$	—31.	.795	—31.	212.–214.	" " "
Tridecylene	$C_{13}H_{26}$	15.	.774	-	233.	Bernthsen.
Tetradecylene	$C_{14}H_{28}$	—12.	.794	—12.	127.‡	Krafft.
Pentadecylene	$C_{15}H_{30}$	-	.814	-	247.	Bernthsen.
Hexadecylene	$C_{16}H_{32}$	4.	.792	4.	155.‡	Krafft, Mendelejeff, etc.
Octadecylene	$C_{18}H_{36}$	18.	.791	18.	179.‡	Krafft.
Eicosylene	$C_{20}H_{40}$	0	.871	-	390.–400.	Beilstein, "Org. Chem."
Cerotene	$C_{27}H_{54}$	-	-	58.	-	Bernthsen.
Melene	$C_{30}H_{60}$	-		62.	-	"

* Liquid at —11.° C. and 180 atmospheres' pressure (Cailletet).
† " " + 4.° " " 46 " " "
‡ Boiling-point under 15 mm. pressure.
§ In vacuo.

DENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

Substance.	Chemical formula.	Temp. C°.	Specific gravity.	Melting-point.	Boiling-point.	Authority.
(c) Acetylene Series: C_nH_{2n-2}.						
Acetylene	C_2H_2	-	-	—81.	—85.	Villard.
Allylene	C_3H_4	-	-	-	-	
Ethylacetylene	C_4H_6	-	-	-	+18.	Bruylants, Kutscheroff, and others.
Propylacetylene	C_5H_8	-	-	-	48.–50.	Bruylants, Taworski.
Butylacetylene	C_6H_{10}	-	-	-	68.–70.	Taworski.
Oenanthylidene	C_7H_{12}	-	-	-	100.–101.	Beilstein, and others.
Caprylidene	C_8H_{14}	0.	0.771	-	133.–134.	Behal.
Undecylidene	$C_{11}H_{20}$	-	-	-	210.–215.	Bruylants.
Dodecylidene	$C_{12}H_{22}$	—9.	.810	—9.	105.*	Krafft.
Tetradecylidene	$C_{14}H_{26}$	+6.5	.806	+6.5	134.*	"
Hexadecylidene	$C_{16}H_{30}$	20.	.804	20.	160.*	"
Octadecylidene	$C_{18}H_{34}$	30.	.802	30.	184.*	"
(d) Monatomic alcohols: $C_nH_{2n+1}OH$.						
Methyl alcohol	CH_3OH	0.	0.812	-	66.	
Ethyl alcohol	C_2H_5OH	0.	.806	—130.†	78.	
Propyl alcohol	C_3H_7OH	0.	.817	-	97.	From Zander, "Lieb.
Butyl alcohol	C_4H_9OH	0.	.823	-	117.	Ann." vol. 224, p. 85,
Amyl alcohol	$C_5H_{11}OH$	0.	.829	-	138.	and Krafft, "Ber."
Hexyl alcohol	$C_6H_{13}OH$	0.	.833	-	157.	vol. 16, 1714,
Heptyl alcohol	$C_7H_{15}OH$	0.	.836	-	176.	" 19, 2221,
Octyl alcohol	$C_8H_{17}OH$	0.	.839	-	195.	" 23, 2360,
Nonyl alcohol	$C_9H_{19}OH$	0.	.842	—5.	213.	and also Wroblewski and Olszewski,
Decyl alcohol	$C_{10}H_{21}OH$	+7.	.839	+7.	231.	"Monatshefte,"
Dodecyl alcohol	$C_{12}H_{25}OH$	24.	.831	24.	143.*	vol. 4, p. 338.
Tetradecyl alcohol	$C_{14}H_{29}OH$	38.	.824	38.	167.*	
Hexadecyl alcohol	$C_{16}H_{33}OH$	50.	.818	50.	190.*	
Octadecyl alcohol	$C_{18}H_{37}OH$	59.	.813	59.	211.*	
(e) Alcoholic ethers: $C_nH_{2n+2}O$.						
Dimethyl ether	C_2H_6O	-	-	-	—23.6	Erlenmeyer, Kreichbaumer.
Diethyl ether	$C_4H_{10}O$	4.	0.731	—117	+34.6	Regnault, Olszewski.
Dipropyl ether	$C_6H_{14}O$	0.	.763	-	90.7	Zander and others.
Di-iso-propyl ether	$C_6H_{14}O$	0.	.743	-	69.	"
Di-n-butyl ether	$C_8H_{18}O$	0.	.784	-	141.	Lieben, Rossi, and others.
Di-sec-butyl ether	$C_8H_{18}O$	21.	.756	-	121.	Kessel.
Di-iso-butyl "	$C_8H_{18}O$	15.	.762	-	122.	Reboul.
Di-iso-amyl "	$C_{10}H_{22}O$	0.	.799	-	170.–175.	Wurtz.
Di-sec-hexyl "	$C_{12}H_{26}O$	-	-	-	203.–208.	Erlenmeyer and Wanklyn.
Di-norm-octyl "	$C_{16}H_{34}O$	17.	.805	-	280.–282.	Moslinger.
(f) Ethyl ethers: $C_nH_{2n+2}O$.						
Ethyl-methyl ether	C_3H_8O	0.	0.725	-	11.	Wurtz, Williamson.
" propyl "	$C_5H_{12}O$	20.	0.739	-	63.–64.	Chancel, Brühl.
" iso-propyl ether	$C_5H_{12}O$	0.	.745	-	54.	Markownikow.
" norm-butyl ether	$C_6H_{14}O$	0.	.769	-	92.	Lieben, Rossi.
" iso-butyl ether	$C_6H_{14}O$	-	.751	-	78.–80.	Wurtz.
" iso-amyl ether	$C_7H_{16}O$	18.	.764	-	112.	Williamson and others.
" norm-hexyl ether	$C_8H_{18}O$	-	-	-	134.–137.	Lieben, Janeczek.
" norm-heptyl ether	$C_9H_{20}O$	16.	.790	-	165.	Cross.
" norm-octyl ether	$C_{10}H_{22}O$	17.	.794	-	182.–184.	Moslinger.

* Boiling-point under 15 mm. pressure.
† Liquid at —11.° C. and 180 atmospheres' pressure (Cailletet).

TABLE 244 (*concluded*).

DENSITIES, MELTING-POINTS, AND BOILING-POINTS OF SOME ORGANIC COMPOUNDS.

(g) Miscellaneous.

Substance.	Chemical formula.	Density and temperature.		Melting-point, C.	Boiling-point, C.	Authority.
Acetic Acid	CH_3COOH	1.115	0°	16.7	118.5	Young '09
Acetone	CH_3COCH_3	0.812	0°	—94.6	56.1	
Aldehyde	C_2H_4O	0.806	0°	—120.	+20.8	
Aniline	$C_6H_5NH_2$	1.038	0°	—8.	183.9	
Beeswax		0.96±		62.		
Benzoic Acid	$C_7H_6O_2$	1.293	4	121.	249.	
Benzol	C_6H_6	0.879	20	5.58	80.2	Young
Benzophenone	$(C_6H_5)_2CO$	1.090	50	48.	305.9	Holborn-Henning
Butter		0.86–7		30.±		
Camphor	$C_{10}H_{16}O$	0.99	10	176.	209.	
Carbolic Acid	C_6H_5OH	1.060	21	43.	182.	
Carbon bisulphide	CS_2	1.292	0	—110.	46.2	
" tetrachloride	CCl_4	1.582	21	—30.	76.7	Young
Chlorbenzene	C_6H_5Cl	1.111	15	—40.	132.	
Chloroform	$CHCl_3$	1.257	0	—65.	61.2	
Cyanogen	C_2N_2			—35.	—21.	
Ethyl bromide	C_2H_5Br	1.45	15	—117.	38.4	
„ chloride	C_2H_5Cl	0.918	8	—141.6	14.	
„ ether	$C_4H_{10}O$	0.736	0	—118.	34.6	
„ iodide	C_2H_5I	1.944	14		72.	
Formic acid	$HCOOH$	1.242	0	8.6	100.8	
Gasolene		0.68±			70–90	
Glucose	$CHO(HCOH)_4CH_2OH$	1.56		146.		
Glycerine	$C_3H_8O_3$	1.269	0	20.	290.	
Iodoform	CHI_3	2.25	25	119.		
Lard				38.±		
Methyl chloride	CH_3Cl	0.992	—24	—103.6	—24.1	
Methyl iodide	CH_3I	2.285	15	—64.	42.3	
Napthalene	$C_6H_4 \cdot C_4H_4$	1.152	15	80.	218.0	Holborn-Henning
Nitrobenzol	$C_6H_5O_2N$	1.212	7.5	5.	211.	
Nitroglycerine	$C_3H_5N_3O_9$	1.60				
Olive oil		0.92			300.±	
Oxalic acid	$C_2H_2O_4 \cdot 2H_2O$	1.68		190.		
Paraffin wax, soft				38–52	350–390	
" " hard				52–56	390–430	
Pyrogallol	$C_6H_3(OH)_3$	1.46	40	133.	293.	
Spermaceti				45.±		
Starch	$C_6H_{10}O_5$	1.56				
Sugar, cane	$C_{12}H_{22}O_{11}$	1.588	20		160.	
Stearine	$(C_{18}H_{35}O_2)_3C_3H_5$	0.925	65			
Tartaric acid	$C_4H_6O_6$	1.754				
Tallow, beef				40–45		
" mutton				44–45		
Toluene	$C_6H_5CH_3$	0.882	00	—92.	111.	
Xylene (o)	$C_6H_4(CH_3)_2$	0.863	20	—28.	142.	
" (m)	"	0.864	20	54.	140.	
" (p)	"	0.861	20	15.	138.	

TRANSFORMATION AND MELTING TEMPERATURES OF LIME-ALUMINA-SILICA COMPOUNDS AND EUTECTIC MIXTURES.

The majority of these determinations are by G. A. Rankin. (Part unpublished.)

Substance.	% CaO	Al_2O_3	SiO_2	Transformation.	Temp.
$CaSiO_3$	48.2	—	51.8	Melting	1540° ± 2°
$CaSiO_3$	48.2	—	51.8	α to β and reverse	1200 ± 2
Ca_2SiO_4	65.	—	35.	Melting	2130 ± 10
"	65.	—	35.	γ to β and reverse	675 ± 5
"	65.	—	35.	β to α and reverse	1420 ± 2
$Ca_3Si_2O_7$	58.2	—	41.8	Dissociation into Ca_2SiO_4 and liquid	1475 ± 5
Ca_3SiO_5	73.6	—	26.4	Dissociation into Ca_2SiO_4 and CaO	1900 ± 5
$Ca_3Al_2O_6$	62.2	37.8	—	Dissociation into CaO and liquid	1535 ± 5
$Ca_5Al_6O_{14}$	47.8	52.2	—	Melting	1455 ± 5
$CaAl_2O_4$	35.4	64.6	—	Melting	1600 ± 5
$Ca_3Al_{10}O_{18}$	24.8	75.2	—	Melting	1720 ± 10
Al_2SiO_5	—	62.8	37.1	Melting	1816 ± 10
$CaAl_2Si_2O_8$	20.1	36.6	43.3	Melting	1550 ± 2
$Ca_2Al_2SiO_7$	40.8	37.2	22.0	Melting	1590 ± 2
$Ca_3Al_2SiO_8$	50.9	30.9	18.2	Dissociation into Ca_2SiO_4 + $Ca_2Al_2SiO_7$ and liquid	1335 ± 5

EUTECTICS.

Crystalline Phases.	% CaO	Al_2O_3	SiO_2	Melting Temp.
$CaSiO_3$, SiO_2	37.	—	63.	1436°
Ca,SiO_3; 3CaO,2SiO_2	54.5	—	45.5	1455±
Ca,SiO_4; CaO.	67.5	—	32.5	2065±
Al_2SiO_5,SiO_2	—	13.	87.	1610
Al_2SiO_5,Al_2O_3	—	64.	36.	1810
$CaAl_2Si_2O_8$; $CaSiO_3$	34.1	18.6	47.3	1299
$CaAl_2Si_2O_8$; SiO_2	10.5	19.5	70.	1359
$CaAl_2Si_2O_8$; SiO_2,$CaSiO_3$	23.2	14.8	62.	1165
$Ca_2Al_2SiO_7$; Ca_2SiO_4	49.6	23.7	26.7	1545
Al_2O_3; $CaAl_2Si_2O_8$	19.3	39.3	41.4	1547
$CaAl_2Si_2O_8$; Al_2SiO_5,SiO_2	9.8	19.8	70.4	1345
$Ca_2Al_2SiO_7$; $Ca_3Al_{10}O_{18}$	35.	50.8	14.2	1552
$Ca_2Al_2SiO_7$; $CaAl_2O_4$	37.8	52.9	9.3	1512
$Ca_2Al_2SiO_7$; $CaAl_2O_4$; $Ca_3Al_{10}O_{18}$	37.5	53.2	9.3	1505
$CaAl_2Si_2O_8$; $Ca_2Al_2SiO_7$	30.2	36.8	33.	1385
$Ca_2Al_2SiO_7$; $Ca_3Si_2O_7$; $CaSiO_3$	47.2	11.8	41.	1310
$Ca_2Al_2SiO_7$; $CaSiO_3$	45.7	13.2	41.1	1316

EUTECTICS.

Crystalline Phases.	% CaO	Al_2O_3	SiO_2	Melting Temp.
$CaAl_2Si_2O_8$; $Ca_2Al_2SiO_7$; $CaSiO_3$	38.	20.	42.	1265°
$CaAl_2Si_2O_8$; $Ca_2Al_2SiO_7$; Al_2O_3	29.2	39.	31.8	1380
Ca_2SiO_4; $CaAl_2O_4$; $Ca_5Al_6O_{14}$	49.5	43.7	6.8	1335

QUINTUPLE POINTS.

Crystalline Phases.	% CaO	Al_2O_3	SiO_2	Melting Temp.
$Ca_2Al_2SiO_7$; Ca_3SiO_7; Ca_2SiO_4	48.2	11.9	39.9	1335
$Ca_2Al_2SiO_7$; Ca_2SiO_4; $CaAl_2O_4$	48.3	42.	9.7	1380
$CaAl_2Si_2O_8$; Al_2O_3; Al_2SiO_5	15.6	36.5	47.9	1512
$Ca_3Al_{10}O_{18}$; $Ca_2Al_2SiO_7$; Al_2O_3	31.2	44.5	24.3	1475

QUADRUPLE POINTS.

Crystalline Phases.	% CaO	Al_2O_3	SiO_2	Melting Temp.
3CaO.2SiO_2; 2CaO.SiO_2	55.5	—	44.5	1475

The accuracy of the melting-points is 5 to 10 units. Geophysical Laboratory. See also Day and Sosman, Am. J. of Sc. xxxi, p. 341, 1911.

Table 246.

LOWERING OF FREEZING-POINTS BY SALTS IN SOLUTION.

In the first column is given the number of gram-molecules (anhydrous) dissolved in 1000 grams of water; the second contains the molecular lowering of the freezing-point; the freezing-point is therefore the product of these two columns. After the chemical formula is given the molecular weight, then a reference number.

g. mol. / 1000 g. H_2O	Molecular Lowering.
$Pb(NO_3)_2$, 331.0: 1, 2.	
0.000362	5.5°
.001204	5.30
.002805	5.17
.005570	4.97
.01737	4.69
.5015	2.99
$Ba(NO_3)_2$, 261.5: 1.	
0.000383	5.6°
.001259	5.28
.002681	5.23
.005422	5.13
.008352	5.04
$Cd(NO_3)_2$, 236.5: 3.	
0.00298	5.4°
.00689	5.25
.01997	5.18
.04873	5.15
$AgNO_3$, 167.0: 4, 5.	
0.1506	3.32°
.5001	2.96
.8645	2.87
1.749	2.27
2.953	1.85
3.856	1.64
0.0560	3.82
.1401	3.58
.3490	3.28
KNO_3, 101.9: 6, 7.	
0.0100	3.5
.0200	3.5
.0500	3.41
.100	3.31
.200	3.19
.250	3.08
.500	2.94
.750	2.81
1.000	2.66
$NaNO_3$, 85.09: 2, 6, 7.	
0.0100	3.6°
.0250	3.46
.0500	3.44
.2000	3.345
.500	3.24
.5015	3.30
1.000	3.15
1.0030	3.03
NH_4NO_3, 80.11: 6, 8.	
0.0100	3.6°
.0250	3.50
0.0500	3.47°
.1000	3.42
.2000	3.32
.500	3.26
1.000	3.14
$LiNO_3$, 69.07: 9.	
0.0398	3.4°
.1671	3.35
.4728	3.35
1.0164	3.49
$Al_2(SO_4)_3$, 342.4: 10.	
0.0131	5.6°
.0261	4.9
.0543	4.5
.1086	4.03
.217	3.83
$CdSO_4$, 208.5: 1, 11.	
0.000704	3.35°
.002685	3.05
.01151	2.69
.03120	2.42
.1473	2.13
.4129	1.80
.7501	1.76
1.253	1.86
K_2SO_4, 174.4: 3, 5, 6, 10, 12.	
0.00200	5.4°
.00398	5.3
.00865	4.9
.0200	4.76
.0500	4.60
.1000	4.32
.200	4.07
.454	3.87
$CuSO_4$, 159.7: 1, 4, 11.	
0.000286	3.3°
.000843	3.15
.002279	3.03
.006670	2.79
.01463	2.59
.1051	2.28
.2074	1.95
.4043	1.84
.8898	1.76
$MgSO_4$, 120.4: 1, 4, 11.	
0.000675	3.29
.002381	3.10
.01263	2.72
.0580	2.65
.2104	2.23
0.4978	2.02°
.8112	2.01
1.5233	2.28
$BaCl_2$, 208.3: 3, 6, 13.	
0.00200	5.5°
.00498	5.2
.0100	5.0
.0200	4.95
.04805	4.80
.100	4.69
.200	4.66
.500	4.82
.586	5.03
.750	5.21
$CdCl_2$, 183.3: 3, 14.	
0.00299	5.0°
.00690	4.8
.0200	4.64
.0541	4.11
.0818	3.93
.214	3.39
.429	3.03
.858	2.71
1.072	2.75
$CuCl_2$, 134.5: 9.	
0.0350	4.9°
.1337	4.81
.3380	4.92
.7149	5.32
$CoCl_2$, 129.9: 9.	
0.0276	5.0°
.1094	4.9
.2369	5.03
.4399	5.30
.538	5.5
$CaCl_2$, 111.0: 5, 13–16.	
0.0100	5.1°
.05028	4.85
.1006	4.79
.5077	5.33
.946	5.3
2.432	8.2
3.469	11.5
3.829	14.4
0.0478	5.2
.153	4.91
.331	5.15
.612	5.47
.998	6.34
$MgCl_2$, 95.26: 6, 14.	
0.0100	5.1°
.0500	4.98
.1500	4.96
.3000	5.186
.6099	5.69
KCl, 74.60: 9, 17–19.	
0.02910	3.54°
.05845	3.46
.112	3.43
.3139	3.41
.476	3.37
1.000	3.286
1.989	3.25
3.269	3.25
$NaCl$, 58.50: 3, 20, 12, 16.	
0.00399	3.7°
.01000	3.67
.0221	3.55
.04949	3.51
.1081	3.48
.2325	3.42
.4293	3.37
.700	3.43
NH_4Cl, 53.52: 6, 15.	
0.0100	3.6°
.0200	3.56
.0350	3.50
.1000	3.43
.2000	3.396
.4000	3.393
.7000	3.41
$LiCl$, 42.48: 9, 15.	
0.00992	3.7°
.0455	3.5
.09952	3.53
.2474	3.50
.5012	3.61
.7939	3.71
$BaBr_2$, 297.3: 14.	
0.100	5.1°
.150	4.9
.200	5.00
.500	5.18
$AlBr_3$, 267.0: 9.	
0.0078	1.4°
.0559	1.2
.1971	1.07
.4355	1.07

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Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

LOWERING OF FREEZING-POINTS BY SALTS IN SOLUTION (*continued*).

g. mol. / 1000 g. H_2O	Molecular Lowering.
$CdBr_2$, 272.3: 3, 14.	
0.00324	5.1°
.00718	4.6
.03627	3.84
.0719	3.39
.1122	3.18
.220	2.96
.440	2.76
.800	2.59
$CuBr_2$, 223.5: 9.	
0.0242	5.1°
.0817	5.1
.2255	5.27
.6003	5.89
$CaBr_2$, 200.0: 14.	
0.0871	5.1°
.1742	5.18
.3484	5.30
.5226	5.64
$MgBr_2$, 184.28: 14.	
0.0517	5.4°
.103	5.16
.207	5.26
.517	5.85
KBr, 119.1: 9, 21.	
0.0305	3.61°
.1850	3.49
.6801	3.30
.250	3.78
.500	3.56
CdI_2, 366.1: 3, 5, 22.	
0.00210	4.5°
.00626	4.0
.02062	3.52
.04857	2.70
.1360	2.35
.333	2.13
.684	2.23
.888	2.51
KI, 166.0: 9, 2.	
0.0651	3.5°
.2782	3.50
.6030	3.42
1.003	3.37
SrI_2, 341.3: 22.	
0.054	5.1°
.108	5.2
.216	5.35
.327	5.52
NaOH, 40.06: 15.	
0.02002	3.45°
.05005	3.45
.1001	3.41
.2000	3.407

g. mol. / 1000 g. H_2O	Molecular Lowering.
KOH, 56.16: 1, 15, 23.	
0.00352	3.60°
.00770	3.59
.02002	3.44
.05006	3.43
.1001	3.42
.2003	3.424
.230	3.50
.465	3.57
CH_3OH, 32.03: 24, 25.	
0.0100	1.8°
.0301	1.82
.2018	1.811
1.046	1.86
3.41	1.88
6.200	1.944
C_2H_5OH, 46.04: 1, 12, 17, 24–27	
0.000402	1.67°
.004993	1.67
.0100	1.81
.02892	1.707
.0705	1.85
.1292	1.829
.2024	1.832
.5252	1.834
1.0891	1.826
1.760	1.83
3.901	1.92
7.91	2.02
11.11	2.12
18.76	1.81
0.0173	1.80
.0778	1.79
K_2CO_3, 138.30: 6	
0.0100	5.1°
.0200	4.93
.0500	4.71
.100	4.54
.200	4.39
Na_2CO_3, 106.10: 6.	
0.0100	5.1°
.0200	4.93
.0500	4.64
.1000	4.42
.2000	4.17
Na_2SO_3, 126.2: 28.	
0.1044	4.51°
.3397	3.74
.7080	3.38
Na_2HPO_4, 142.1: 22, 29.	
0.01001	5.0°
.02003	4.84
.05008	4.60
.1002	4.34

g. mol / 1000 g. H_2O	Molecular Lowering.
Na_2SiO_3, 122.5: 15.	
0.01052	6.4°
.05239	5.86
.1048	5.28
.2099	4.66
.5233	3.99
HCl, 36.46: 1–3, 6, 13, 18, 22.	
0.00305	3.68°
.00695	3.66
.0100	3.6
.01703	3.59
.0500	3.59
.1025	3.56
.2000	3.57
.3000	3.612
.464	3.68
.516	3.79
1.003	3.95
1.032	4.10
1.500	4.42
2.000	4.97
2.115	4.52
3.000	6.03
3.053	4.90
4.065	5.67
4.657	6.19
HNO_3, 63.05: 3, 13, 15.	
0.02004	3.55°
.05015	3.50
.0510	3.71
.1004	3.48
.1059	3.53
.2015	3.45
.250	3.50
.500	3.62
1.000	3.80
2.000	4.17
3.000	4.64
H_3PO_2, 66.0: 29.	
0.1260	2.90°
.2542	2.75
.5171	2.59
1.071	2.45
HPO, 82 0: 4, 5.	
0.0745	3.0°
.1241	2.8
.2482	2.6
1.00	2.39
H_3PO_4, 98.0: 6, 22.	
0.0100	2.8°
.0200	2.68
.0500	2.49
.1000	2.36
.2000	2.25

g. mol. / 1000 g. H_2O	Molecular Lowering.
0.472	2.20°
.944	2.27
1.620	2.60
$(COOH)_2$, 90.02: 4, 15.	
0.01002	3.3°
.02005	3.19
.05019	3.03
.1006	2.83
.2022	2.64
.366	2.56
.648	2.3
$C_3H_5(OH)_3$, 92.06: 24, 25.	
0.0200	1.86°
.1008	1.86
.2031	1.85
.535	1.91
2.40	1.98
5.24	2.13
$(C_2H_5)_2O$, 74.08: 24	
0.0100	1.6°
.0201	1.67
.1011	1.72
.2038	1.702
Dextrose, 180.1: 24, 30.	
0.0198	1.84°
.0470	1.85
.1326	1.87
.4076	1.894
1.102	1.921
Levulose, 180.1: 24, 25.	
0.0201	1.87°
.2050	1.871
.554	2.01
1.384	2.32
2.77	3.04
CHO, 342.2: 1, 24, 26.	
0.000332	1.90°
.001410	1.87
.009978	1.86
.0201	1.88
.1305	1.88
H_2SO_4, 98.08: 13, 20, 31–33.	
0.00461	4.8°
.0100	4.49
.0200	4.32
.0461	4.10
.100	3.96
.200	3.85
.400	3.98
1.000	4.19
1.500	4.96
2.000	5.65
2.500	6.53

1–20 *See* page 217.
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Table 247.

RISE OF BOILING-POINT PRODUCED BY SALTS DISSOLVED IN WATER.*

This table gives the number of grams of the salt which, when dissolved in 100 grams of water, will raise the boiling-point by the amount stated in the headings of the different columns. The pressure is supposed to be 76 centimeters.

Salt.	1° C.	2°	3°	4°	5°	7°	10°	15°	20°	25°
$BaCl_2 + 2H_2O$	15.0	31.1	47.3	63.5	(71.6 gives 4°.5 rise of temp.)					
$CaCl_2$	6.0	11.5	16.5	21.0	25.0	32.0	41.5	55.5	69.0	84.5
$Ca(NO_3)_2 + 2H_2O$	12.0	25.5	39.5	53.5	68.5	101.0	152.5	240.0	331.5	443.5
KOH	4.7	9.3	13.6	17.4	20.5	26.4	34.5	47.0	57.5	67.3
$KC_2H_3O_2$	6.0	12.0	18.0	24.5	31.0	44.0	63.5	98.0	134.0	171.5
KCl	9.2	16.7	23.4	29.9	36.2	48.4	(57.4 gives a rise of 8°.5)			
K_2CO_3	11.5	22.5	32.0	40.0	47.5	60.5	78.5	103.5	127.5	152.5
$KClO_3$	13.2	27.8	44.6	62.2						
KI	15.0	30.0	45.0	60.0	74.0	99.5	134.	185.0	(220 gives 18°.5)	
KNO_3	15.2	31.0	47.5	64.5	82.0	120.5	188.5	338.5		
$K_2C_4H_4O_6 + \frac{1}{2}H_2O$	18.0	36.0	54.0	72.0	90.0	126.5	182.0	284.0		
$KNaC_4H_4O_6$	17.3	34.5	51.3	68.1	84.8	119.0	171.0	272.5	390.0	510.0
$KNaC_4H_4O_6 + 4H_2O$	25.0	53.5	84.0	118.0	157.0	266.0	554.0	5510.0		
$LiCl$	3.5	7.0	10.0	12.5	15.0	20.0	26.0	35.0	42.5	50.0
$LiCl + 2H_2O$	6.5	13.0	19.5	26.0	32.0	44.0	62.0	92.0	123.0	160.5
$MgCl_2 + 6H_2O$	11.0	22.0	33.0	44.0	55.0	77.0	110.0	170.0	241.0	334.5
$MgSO_4 + 7H_2O$	41.5	87.5	138.0	196.0	262.0					
$NaOH$	4.3	8.0	11.3	14.3	17.0	22.4	30.0	41.0	51.0	60.1
$NaCl$	6.6	12.4	17.2	21.5	25.5	33.5	(40.7 gives 8°.8 rise)			
$NaNO_3$	9.0	18.5	28.0	38.0	48.0	68.0	99.5	156.0	222.0	
$NaC_2H_3O_2 + 3H_2O$	14.9	30.0	46.1	62.5	79.7	118.1	194.0	480.0	6250.0	
$Na_2S_2O_3$	14.0	27.0	39.0	49.5	59.0	77.0	104.0	152.0	214.5	311.0
Na_2HPO_4	17.2	34.4	51.4	68.4	85.3					
$Na_2C_4H_4O_6 + 2H_2O$	21.4	44.4	68.2	93.9	121.3	183.0	(237.3 gives 8°.4 rise)			
$Na_2S_2O_3 + 5H_2O$	23.8	50.0	78.6	108.1	139.3	216.0	400.0	1765.0		
$Na_2CO_3 + 10H_2O$	34.1	86.7	177.6	369.4	1052.9					
$Na_2B_4O_7 + 10H_2O$	39.	93.2	254.2	898.5	(5555.5 gives 4°.5 rise)					
NH_4Cl	6.5	12.8	19.0	24.7	29.7	39.6	56.2	88.5		
NH_4NO_3	10.0	20.0	30.0	41.0	52.0	74.0	108.0	172.0	248.0	337.0
NH_4SO_4	15.4	30.1	44.2	58.0	71.8	99.1	(115.3 gives 10°.2)			
$SrCl_2 + 6H_2O$	20.0	40.0	60.0	81.0	103.0	150.0	234.0	524.0		
$Sr(NO_3)_2$	24.0	45.0	63.6	81.4	97.6					
$C_4H_6O_6$	17.0	34.4	52.0	70.0	87.0	123.0	177.0	272.0	374.0	484.0
$C_2H_2O_4 + 2H_2O$	19.0	40.0	62.0	86.0	112.0	169.0	262.0	540.0	1316.0	50000.0
$C_6H_8O_7 + H_2O$	29.0	58.0	87.0	116.0	145.0	208.0	320.0	553.0	952.0	

Salt.	40°	60°	80°	100°	120°	140°	160°	160°	200°	240°
$CaCl_2$	137.5	222.0	314.0							
KOH	92.5	121.7	152.6	185.0	219.8	263.1	312.5	375.0	444.4	623.0
$NaOH$	93.5	150.8	230.0	345.0	526.3	800.0	1333.0	2353.0	6452.0	–
NH_4NO_3	682.0	1370.0	2400.0	4099.0	8547.0	∞				
$C_4H_6O_6$	980.0	3774.0	(infinity gives 170)							

* Compiled from a paper by Gerlach, "Zeit. f. Anal. Chem." vol. 26.

Table 248.

FREEZING MIXTURES.*

Column 1 gives the name of the principal refrigerating substance, *A* the proportion of that substance, *B* the proportion of a second substance named in the column, *C* the proportion of a third substance, *D* the temperature of the substances before mixture, *E* the temperature of the mixture, *F* the lowering of temperature, *G* the temperature when all snow is melted, when snow is used, and *H* the amount of heat absorbed in heat units (small calories when *A* is grams). Temperatures are in Centigrade degrees.

Substance.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
$NaC_2H_3O_2$ (cryst.)	85	H_2O–100	–	10.7	−4.7	15.4	–	–
NH_4Cl	30	" "	–	13.3	−5.1	18.4	–	–
$NaNO_3$	75	" "	–	13.2	−5.3	18.5	–	–
$Na_2S_2O_3$ (cryst.)	110	" "	–	10.7	−8.0	18.7	–	–
KI	140	" "	–	10.8	−11.7	22.5	–	–
$CaCl_2$ (cryst.)	250	" "	–	10.8	−12.4	23.2	–	–
NH_4NO_3	60	" "	–	13.6	−13.6	27.2	–	–
$(NH_4)_2SO_4$	25	" 50	NH_4NO_3–25	–	–	26.0	–	–
NH_4Cl	25	" "	" "	–	–	22.0	–	–
$CaCl_2$	25	" "	" "	–		20.0	–	–
KNO_3	25	" "	NH_4Cl–25	–	–	20.0	–	–
Na_2SO_4	25	" "	" "	–	–	19.0	–	–
$NaNO_3$	25	" "	" "	–	–	17.0	–	–
K_2SO_4	10	Snow 100	–	−1	−1.9	0.9	–	
Na_2CO_3 (cryst.)	20	" "	–	−1	−2.0	1.0	–	–
KNO_3	13	" "	–	−1	−2.85	1.85	–	
$CaCl_2$	30	" "	–	−1	−10.9	9.9	–	–
NH_4Cl	25	" "	–	−1	−15.4	14.4	–	
NH_4NO_3	45	" "	–	−1	−16.75	15.75	–	–
$NaNO_3$	50	" "	–	−1	−17.75	16.75		
NaCl	33	" "	–	−1	−21.3	20.3	–	
$H_2SO_4 + H_2O$ (66.1 % H_2SO_4)	1	" 1.097	–	−1	−37.0	36.0	−37.0	0.0
	1	" 1.26	–	−1	−36.0	35.0	−30.2	17.0
	1	" 1.38	–	−1	−35.0	34.0	−25.0	27.0
	1	" 2.52	–	−1	−30.0	29.0	−12.4	133.0
	1	" 4.32	–	−1	−25.0	24.0	−7.0	273.0
	1	" 7.92		−1	−20.0	19.0	−3.1	553.0
	1	" 13.08	–	−1	−16.0	15.0	−2.1	967.0
$CaCl_2 + 6H_2O$	1	" 0.35	–	0	–	–	0.0	52.1
	1	" .49		0	–		−19.7	49.5
	1	" .61	–	0	–	–	−39.0	40.3
	1	" .70	–	0	–	–	−54.9†	30.0
	1	" .81	–	0	–	–	−40.3	46.8
	1	" 1.23	–	0	–	–	−21.5	88.5
	1	" 2.46	–	0	–	–	−9.0	192.3
	1	" 4.92	–	0	–	–	−4.0	392.3
Alcohol at 4°	77	" 73	–	0	−30.0	–	–	–
	–	CO_2 solid	–	–	−72.0	–	–	–
Chloroform	–	" "	–	–	−77.0	–	–	–
Ether	–	" "	–	–	−77.0	–	–	–
Liquid SO_2	–	" "	–	–	−82.0		–	–
NH_4NO_3	1	H_2O–.75	–	20	5.0	–	–	33.0
	1	" .94		20	−4.0	–	–	21.0
	1	" "	–	10	−4.0	–	–	34.0
	1	" "	–	5	−4.0	–	–	40.5
	1	Snow "	–	0	−4.0	–	–	122.2
	1	H_2O–1.20		10	−14.0	–	–	17.9
	1	Snow "	–	0	−14.0	–	–	129.5
	1	H_2O–1.31	–	10	−17.5†	–	–	10.6
	1	Snow "	–	0	−17.5†	–	–	131.9
	1	H_2O–3.61	–	10	−8.0	–	–	0.4
	1	Snow "	–	0	−8.0	–	–	327.0

* Compiled from the results of Cailletet and Colardeau, Hammerl, Hanamann, Moritz, Pfaundler, Rudorf, and Tollinger.

† Lowest temperature obtained.

CRITICAL TEMPERATURES, PRESSURES, VOLUMES, AND DENSITIES OF GASES.*

θ = Critical temperature.
P = Critical pressure in atmospheres.
ϕ = Critical volume referred to volume at 0° and 76 centimeters pressure.
d = Critical density in grams per cubic centimeter.

a, b, Van der Waals constants in $\left(p + \frac{a^2}{v^2}\right)\left(v - b\right) = 1 + \alpha t.$

Substance.	θ	P	ϕ	d	a × 10⁵	b × 10⁶	Observer
Air	—140.0	39.0	–	–	257	1560	1
Alcohol (C_2H_6O)	243.6	62.76	0.00713	0.288	2407	3769	2
" (CH_4O)	239.95	78.5	–	–	1898	2992	3
Ammonia	130.0	115.0	–	–	798	1606	4
Argon	—117.4	52.9	–	–	259	1348	5
Benzol	288.5	47.9	–	0.305	3726	5370	3
Bromine	302.2	–	0.00605	1.18	1434	2020	6
Carbon dioxide	31.2	73.	0.0044	0.46	717	1908	–
" monoxide	—141.1	35.9	–	–	275	1683	7
" disulphide	277.7	78.1	–	–	2197	3227	8
Chloroform	260.0	54.9	–	–	2930	4450	9
Chlorine	141.0	83.9	–		1157	2259	4
"	146.0	93.5	–	–	1063	2050	10
Ether	197.0	35.77	0.01584	0.208	3496	6016	11
"	194.4	35.61	0.01344	0.262	3464	6002	3
Ethane	32.1	49.0	–	–	1074	2848	12
Ethylene	9.9	51.1		–	886	2533	–
Helium	<—268.0	–	–	–	5	700	13
Hydrogen	—240.8	14.	–	–	42	880	14
" chloride	51.25	86.0	–	–	692	1726	15
" "	52.3	86.0	–	0.61	697	1731	4
" sulphide	100.0	88.7	–	–	888	1926	1
Krypton	—62.5	54.3	–		462	1776	5
Methane	—81.8	54.9		–	376	1557.	1
"	—95.5	50.0	–	–	357	1625	4
Neon	<—205.0	29.	–	–	–	–	5,13
Nitric oxide (NO)	—93.5	71.2	–	–	257	1160	1
Nitrogen	—146.0	35.0	–	0.44	259	1650	1
" monoxide (N_2O)	35.4	75.0	0.0048	0.41	720	1888	4,17
Oxygen	—118.0	50.0	–	0.6044	273	1420	1
Sulphur dioxide	155.4	78.9	0.00587	0.49	1316	2486	9,17
Water	358.1	–	0.001874	0.429	–	–	6
"	374.	217.5	–	–	1089	1362	16

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*Abridged for the most part from Landolt and Börnstein's "Phys. Chem. Tab."

LINEAR EXPANSION OF THE ELEMENTS.

In the heading of the columns t is the temperature or range of temperature; C is the coefficient of linear expansion; A_1 is the authority for C; M is the mean coefficient of expansion between 0° and 100° C.; α and β are the coefficients in the equation $l_t = l_0 (1 + \alpha t + \beta t^2)$, where l_0 is the length at 0° C. and l_t the length at t° C.; A_2 is the authority for α, β, and M.

Substance.	t	$C \times 10^4$	A_1	$M \times 10^4$	$\alpha \times 10^4$	$\beta \times 10^6$	A_2
Aluminum	40	0.2313	1	0.2220	–	–	2
"	600	.3150	3				
"	–191 to +16	.1835	4	–	.23536	.00707	5
Antimony:							
Parallel to cryst. axis	40	.1692	1				
Perp. to axis	40	.0882	1				
Mean	40	.1152	1	.1056	.0923	.0132	6
Arsenic	40	.0559	1				
Bismuth:							
Parallel to axis	40	.1621	1				
Perp. to axis	40	.1208	1				
Mean	40	.1346	1	.1316	.1167	.0149	6
Cadmium	40	.3069	1	.3159	.2693	.0466	6
Carbon:							
Diamond	40	.0118	1				
Gas carbon	40	.0540	1				
Graphite	40	.0786	1		.0055	.0016	13
Anthracite	40	.2078	1				
Cobalt	40	.1236	1				
Copper	40	.1678	1	.1666	.1481	.0185	6
"	–191 to +16	.1409	4		.16070	.00403	5
Gold	40	.1443	1	.1470	.1358	.0112	6
Indium	40	.4170	1				
Iron:							
Soft	40	.1210	1				
Cast	40	.1061	1				
"	–191 to +16	.0850	4				
Wrought	–18 to 100	.1140	7	–	.11705	.005254	8
Steel	40	.1322	1	–	.09173	.008336	8
" annealed	40	.1095	1	.1089	.1038	.0052	9
Lead	40	.2924	1	.2709	.273	.0074	6
Magnesium	40	.2694	1				
Nickel	40	.1279	1		.13460	.003315	8
"	–191 to +16	.1012	4				
Osmium	40	.0657	1				
Palladium	40	.1176	1	–	.11670	.002187	8
Phosphorus	0–40	1.2530	10				
Platinum	40	0.0899	1	–	.08868	.001324	8
Potassium	0–50	.8300	11				
Rhodium	40	.0850	1				
Ruthenium	40	.0963	1				
Selenium	40	.3680	1	.6604	–	–	12
Silicon	40	.0763	1				
Silver	40	.1921	1	–	.18270	.004793	8
"	–191 to +16	.1704	4				
Sulphur:							
Cryst. mean	40	.6413	1	1.180	–	–	12
Tellurium	40	.1675	1	.3687	–	–	12
Thallium	40	.3021	1				
Tin	40	.2234	1	.2296	.2033	.0263	6
Zinc	40	.2918	1	.2976	.2741	.0234	6

1 Fizeau.
2 Calvert, Johnson and Lowe.
3 Chatelier.
4 Henning.
5 Dittenberger.
6 Matthiessen.
7 Andrews.
8 Holborn-Day.
9 Benoit.
10 Pisati and De Franchis.
11 Hagen.
12 Spring.
13 Day and Sosman.

The above table has been partly compiled from the results published by Fizeau, "Comptes Rendus," vol. 68, and Matthiessen, "Proc. Roy. Soc.," vol. 15.
The Holborn-Day and Day and Sosman data are for temperatures from 20° to 1000° C. The Dittenberger, 0° to 600° C.

LINEAR EXPANSION OF MISCELLANEOUS SUBSTANCES.

The coefficient of cubical expansion may be taken as three times the linear coefficient. *t* is the temperature or range of temperature, *C* the coefficient of expansion, and *A* the authority.

Substance.	*t*	$C \times 10^4$	*A*.	Substance.	*t*	$C \times 10^4$	*A*.
Brass:				Platinum-silver:			
Cast	0–100	0.1875	1	1Pt+2Ag	0–100	0.1523	4
Wire	"	0.1930	1	Porcelain	20–790	0.0413	19
—	"	.1783–.193	2	" Bayeux	1000–1400	0.0553	20
71.5Cu+27.7Zn+0.3Sn+0.5Pb	40	0.1859	3	Quartz: Parallel to axis	0–80	0.0797	6
71Cu+29Zn	0–100	0.1906	4	" " "	−190 to +16	.0521	21
Bronze:				Perpend." "	0–80	0.1337	6
3Cu+1Sn	16.6–100	0.1844	5	Quartz glass	−190 to +16	−.0026	13
" "	16.6–350	0.2116	5	Rock salt	40	0.4040	3
" "	16.6–957	0.1737	5	Speculum metal	0–100	0.1933	1
86.3Cu+9.7Sn+4Zn	40	0.1782	3	Topaz:			
97.6Cu+2.2Sn+0.2P, hard	0–80	0.1713	6	Parallel to lesser horizontal axis	"	0.0832	8
97.6Cu+2.2Sn+0.2P, soft	"	0.1708	6	Parallel to greater horizontal axis	"	0.0836	8
Caoutchouc	–	.657–.686	2	Parallel to vertical axis	"	0.0472	8
"	16.7–25.3	0.770	7	Tourmaline:			
Constantine	4–29	0.1523	–	Parallel to longitudinal axis	"	0.0937	8
Ebonite	25.3–35.4	0.842	7	Parallel to horizontal axis	"	0.0773	8
Fluor spar: CaF_2	0–100	0.1950	8	Type metal	16.6–254	0.1952	5
German silver	"	0.1836	8	Vulcanite	0–18	0.6360	22
Gold-platinum: 2Au+1Pt	"	0.1523	4	Wedgwood ware	0–100	0.0890	5
Gold-copper: 2Au+1Cu	"	0.1552	4	Wood:			
Glass:				Parallel to fibre:			
Tube	"	0.0833	1	Ash	"	0.0951	23
"	"	0.0828	9	Beech	2–34	0.0257	24
Plate	"	0.0891	10	Chestnut	"	0.0649	24
Crown (mean)	"	0.0897	10	Elm	"	0.0565	24
"	50–60	0.0954	11	Mahogany	"	0.0361	24
Flint	"	0.0788	11	Maple	"	0.0638	24
Jena thermometer 16^{III} normal	0–100	0.081	12	Oak	"	0.0492	24
" 59^{III}	"	0.058	12	Pine	"	0.0541	24
" "	−191 to +16	0.424	13	Walnut	"	0.0658	24
Gutta percha	20	1.983	14	Across the fibre:			
Ice	−20 to −1	0.51	15	Beech	"	0.614	24
Iceland spar:				Chestnut	"	0.325	24
Parallel to axis	0–80	0.2631	6	Elm	"	0.443	24
Perpendicular to axis	"	0.0544	6	Mahogany	"	0.404	24
Lead-tin (solder) 2Pb+1Sn	0–100	0.2508	1	Maple	"	0.484	24
Magnalium	12–39	0.238	16	Oak	"	0.544	24
Marble	15–100	0.117	17	Pine	"	0.341	24
Paraffin	0–16	1.0662	18	Walnut	"	0.484	24
"	16–38	1.3030	18	Wax: White	10–26	2.300	25
"	38–49	4.7707	18	"	26–31	3.120	25
Platinum-iridium 10Pt+1Ir	40	0.0884	3	"	31–43	4.860	25
				"	43–57	15.227	25

1 Smeaton.
2 Various.
3 Fizeau.
4 Matthiessen.
5 Daniell.
6 Benoit.
7 Kohlrausch.
8 Pfaff.
9 Deluc.
10 Lavoisier and Laplace.
11 Pulfrich.
12 Schott.
13 Henning.
14 Russner.
15 Mean.
16 Stadthagen.
17 Fröhlich.
18 Rodwell.
19 Braun.
20 Deville and Troost.
21 Scheel.
22 Mayer.
23 Glatzel.
24 Villari.
25 Kopp.

TABLE 252.

CUBICAL EXPANSION OF SOLIDS.

If v_2 and v_1 are the volumes at t_2 and t_1 respectively, then $v_2 = v_1 (1 + C\Delta t)$, C being the coefficient of cubical expansion and Δt the temperature interval. Where only a single temperature is stated C represents the true coefficient of cubical expansion at that temperature.*

Substance.	t or Δt	$C \times 10^4$	Authority.
Antimony	0–100	0.3167	Matthiessen
Beryl	0–100	0.0105	Pfaff
Bismuth	0–100	0.3948	Matthiessen
Copper	0–100	0.4998	"
Diamond	40	0.0354	Fizeau
Emerald	40	0.0168	"
Galena	0–100	0.558	Pfaff
Glass, common tube	0–100	0.276	Regnault
" hard	0–100	0.214	"
" Jena, borosilicate 59 III	20–100	0.156	Scheel
" pure silica	0–80	0.0129	Chappuis
Gold	0–100	0.4411	Matthiessen
Ice	—20—1	1.1250	Brunner
Iron	0–100	0.3550	Dulong and Petit
Lead	0–100	0.8399	Matthiessen
Paraffin	20	5.88	Russner
Platinum	0–100	0.265	Dulong and Petit
Porcelain, Berlin	20	0.0814	Chappuis and Harker
Potassium chloride	0–100	1.094	Playfair and Joule
" nitrate	0–100	1.967	" " "
" sulphate	20	1.0754	Tutton
Quartz	0–100	0.3840	Pfaff
Rock salt	50–60	1.2120	Pulfrich
Rubber	20	4.87	Russner
Silver	0–100	0.5831	Matthiessen
Sodium	20	2.1364	E. Hazen
Stearic acid	33.8–45.5	8.1	Kopp
Sulphur, native	13.2–50.3	2.23	"
Tin	0–100	0.6889	Matthiessen
Zinc	0–100	0.8928	"

* For tables of cubical expansion complete to 1876, see Clark's Constants of Nature, Smithsonian Collections, 289.

Table 253.

CUBICAL EXPANSION OF LIQUIDS.

If V_0 is the volume at 0° then at t° the expansion formula is $V_t = V_0(1 + \alpha t + \beta t^2 + \gamma t^3)$. The table gives values of α, β and γ and of C, the true coefficient of cubical expansion, at 20° for some liquids and solutions. Δt is the temperature range of the observation and A the authority.

Liquid.	Δt	$\alpha\ 10^3$	$\beta\ 10^6$	$\gamma\ 10^8$	$C\ 10^3$ at 20°	A
Acetic acid	16–107	1.0630	0.12636	1.0876	1.071	3
Acetone	0–54	1.3240	3.8090	—0.87983	1.487	3
Alcohol:						
Amyl	—15–80	8.9001	0.6573	1.18458	0.902	4a
Ethyl, 30% by vol.	18–39	0.2928	10.790	—11.87	-	6
" 50% "	0–39	0.7450	1.85	0.730	-	6
" 99.3% "	27–46	1.012	2.20	-	1.12	6
" 500 atmo. press.	0–40	0.866	-	-	-	1
" 3000 " "	0–40	0.524	-	-	-	1
Methyl	0–61	1.1342	1.3635	0.8741	1.199	5a
Benzol	11–81	1.17626	1.27776	0.80648	1.237	5a
Bromine	0–59	1.06218	1.87714	—0.30854	1.132	2
Calcium chloride:						
5.8% solution	18–25	0.07878	4.2742	-	0.250	7
40.9% "	17–24	0.42383	0.8571	-	0.458	7
Carbon disulphide	—34–60	1.13980	1.37065	1.91225	1.218	4a
500 atmos. pressure	0–50	0.940	-	-	-	1
3000 " "	0–50	0.581	-	-	-	1
Carbon tetrachloride	0–76	1.18384	0.89881	1.35135	1.236	4b
Chloroform	0–63	1.10715	4.66473	—1.74328	1.273	4b
Ether	—15–38	1.51324	2.35918	4.00512	1.656	4a
Glycerine	-	0.4853	0.4895	-	0.505	8
Hydrochloric acid:						
33.2% solution	0–33	0.4460	0.215	-	0.455	9
Mercury	0–100	0.18182	0.0078	-	1.8186	13
Olive oil	-	0.6821	1.1405	—0.539	0.721	10
Pentane	0–33	1.4646	3.09319	1.6084	1.608	14
Potassium chloride:						
24.3% solution	16–25	0.2695	2.080	-	0.353	7
Phenol	36–157	0.8340	0.10732	0.4446	1.090	11
Petroleum:						
Density 0.8467	24–120	0.8994	1.396	-	0.955	12
Sodium chloride:						
20.6% solution	0–29	0.3640	1.237		0.414	9
Sodium sulphate:						
24% solution	11–40	0.3599	1.258	-	0.410	9
Sulphuric acid:						
10.9% solution	0–30	0.2835	2.580	-	0.387	9
100.0%	0–30	0.5758	—0.432	-	0.558	9
Turpentine	—9–106	0.9003	1.9595	—0.44998	0.973	5b
Water	0–33	—0.06427	8.5053	6.7900	0.207	13

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TABLE 254.

COEFFICIENTS OF THERMAL EXPANSION.

Coefficients of Expansion of Gases.

Pressures are given in centimeters of mercury.

Coefficient at Constant Volume.

Substance.	Pressure cm.	Coefficient × 100.	Reference.
Air	.6	.37666	1
"	1.3	.37172	"
"	10.0	.36630	"
"	25.4	.36580	"
"	75.2	.36660	"
" 0°–100° . .	100.1	.36744	2
"	76.0	.36650	3
"	200.0	.36903	"
"	2000.	.38866	"
"	10000.	.4100	"
Argon . . .	51.7	.3668	4
Carbon dioxide .	76.0	.36856	3
" " . .	1.8	.36753	1
" " . .	5.6	.36641	"
" " . .	74.9	.37264	"
" " 0°–20°	51.8	.36985	2
" " 0°–40°	51.8	.36972	"
" " 0°–100°	51.8	.36981	"
" " 0°–20°	99.8	.37335	"
" " 0°–100°	99.8	.37262	"
" " 0°–100°	100.0	.37248	5
Carbon monoxide .	76.	.36667	3
Helium . . .	56.7	.3665	4
Hydrogen 16°–132°	.0077	.3328	6
" 15°–132°	.025	.3623	"
" 12°–185°	.47	.3656	"
"	.93	.37002	1
"	11.2	.36548	"
"	76.4	.36504	"
" 0°–100°	100.0	.36626	2
Nitrogen 13°–132°	.06	.3021	6
" 9°–133°	.53	.3290	"
" 0°–20°	100.2	.36754	2
" 0°–100°	100.2	.36744	"
"	76.	.36682	7
Oxygen 11°–132° .	.007	.4161	6
" 9°–132° .	.25	.3984	"
" 11°–132° .	.51	.3831	"
"	1.9	.36683	8
"	18.5	.36690	"
"	75.9	.36681	"
Nitrous oxide .	76.	.3676	3
Sulph'r dioxide SO_2	76.	.3845	"

Coefficient at Constant Pressure.

Substance.	Pressure cm.	Coefficient × 100.	Reference.
Air	76.	.3671	3
"	257.	.3693	"
" 0°–100° . .	100.1	.36728	2
Hydrogen 0°–100°	100.0	.36600	"
"	200 Atm.	.332	9
"	400 "	.295	"
"	600 "	.261	"
"	800 "	.242	"
Carbon dioxide .	76.	.3710	3
" " 0°–20°	51.8	.37128	2
" " 0°–40°	51.8	.37100	"
" " 0°–100°	51.8	.37073	"
" " 0°–20°	99.8	.37602	"
" " 0°–100°	99.8	.37410	"
" " 0°–20°	137.7	.37972	"
" " 0°–100°	137.7	.37703	"
" " 0°–7.5°	2621.	.1097	6
" " 64°–100°	2621.	.6574	"
Carbon monoxide .	76.	.3669	3
Nitrous oxide .	76.	.3719	"
Sulphur dioxide .	76.	.3903	"
" " .	98.	.3980	"
Water-vapor 0°–119°	76.	.4187	10
Water-vapor 0°–141°	76.	.4189	"
Water-vapor 0°–162°	76.	.4071	"
Water-vapor 0°–200°	76.	.3938	"
Water-vapor 0°–247°	76.	.3799	"

Thomson has given, Encyc. Brit. "Heat," the following for the calculation of the expansion, E, between 0° and 100° C. Expansion is to be taken as the change of volume under constant pressure:

Hydrogen, $E = .3662(1 - .00049\,V/v)$,
Air, $E = .3662(1 - .0026\,V/v)$,
Oxygen, $E = .3662(1 - .0032\,V/v)$,
Nitrogen, $E = .3662(1 - .0031\,V/v)$,
CO_2 $E = .3662(1 - .0164\,V/v)$.

V/v is the ratio of the actual density of the gas at 0° C to what it would have at 0° C and 1 Atm. pressure.

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MECHANICAL EQUIVALENT OF HEAT.

TABLE 255.—Summary.

Taken from J. S. Ames, L'équivalent mécanique de la chaleur, Rapports présentés au congrès international du physique, Paris, 1900.

Name.	Method.	Scale.	Result.	Temp. °C.
Joule	Mechanical .	. . . .	4.173	16.5
Rowland . . .	Mechanical .	. . . .	4.195	10.
			4.187	15.
			4.181	20.
			4.176	25.
Reynolds-Morby .	Mechanical .	. . . .	4.1832	Mean-calory.
Griffiths	Electrical . .	Latimer-Clark = 1.4342v at 15°C.	4.198	15.
	$\frac{E^2t}{R}$		4.192	20.
		International Ohm	4.187	25.
Schuster-Gannon	Electrical Eit.	Latimer-Clark = 1.4340v. at 15° C., Elec. Chem. Equiv. Silver = 0.001118g	4.1905	19.1
Callendar-Barnes	Electrical Eit.	Latimer-Clark = 1.4342v. at 15° C.	4.179	40.

TABLE 256.—Reduced to Gram-calory at 20° C. (Nitrogen thermometer).

		*
Joule	4.169×10^7 ergs	4.169×10^7 ergs.
Rowland . . .	4.181 " "	4.181 " "
Griffiths	4.192 " "	4.184 " "
Schuster-Gannon	4.189 " "	4.181 " "
Callendar-Barnes	4.186 " "	4.178 " "

* Admitting an error of 1 part per 1000 in the electrical scale.

The mean of the last four then gives

1 small (20° C) calory = 4.181×10^7 ergs.

1 small (15° C) calory = 4.185×10^7 ergs assuming sp. ht. of water at 20° = 0.9990.

TABLE 257.—Conversion Factors for Units of Work.

	Joules Watts × sec. Volt-amp. per sec.	Small 15° Calories.	Ergs.	Kilo-gram-meters.	Foot-poundals.	Foot-pounds.
1 joule = 1 watt × second	1	0.2389	10^7	$\frac{1}{g^*}$	23.73	$\frac{23.73}{g\dagger}$
1 small 15° calory =	4.185	1	4.185×10^7	$\frac{4.185}{g^*}$	99.31	$\frac{99.31}{g\dagger}$
1 erg =	10^{-7}	0.2389×10^{-7}	1	$\frac{10^{-7}}{g^*}$	23.73×10^{-7}	$\frac{23.73}{g\dagger} \times 10^{-7}$
1 kilog.-meter =	g*	0.2389g*	$g^* \times 10^7$	1	23.73g*	23.73
1 foot-poundal =	.04214	.01007	421400.	$\frac{.04214}{g^*}$	1	$\frac{1}{g\dagger}$
1 foot-pound =	.04214g†	.01007g†	421400g†	.04214	g†	1

* g = 9.80 m. per sec. per sec. at latitude 45°, sea level.
† g = 32.2 ft. per sec. per sec. " " " " "

TABLE 258.

SPECIFIC HEAT OF THE CHEMICAL ELEMENTS.

Element.	Range * of Temperature, °C.	Specific heat.	Reference.	Element.	Range * of Temperature, °C.	Specific heat.	Reference.
Aluminum	—250	0.1428	1	Iodine	9–98	0.0541	25
"	0	.2089	"	Iridium	—186–+18	.0282	26
"	100	.2226	"	"	18–100	.0323	"
"	250	.2382	"	Iron, cast	20–100	.1189	27
"	500	.2739	"	" wrought	15–100	.1152	28
"	16–100	.2122	43	" "	1000–1200	.1989	"
Antimony	15	.0489	2	" "	500	.176	"
"	100	.0503	"	" hard-drawn	0–18	.0986	29
"	200	.0520	"	" " "	20–100	.1146	"
Arsenic, gray	0–100	.0822	3	"	—185–+20	.0958	4
" black	0–100	.0861	"	Lanthanum	0–100	.0448	15
Barium	—185–+20	.068	4	Lead	15	.0299	2
Bismuth	—186	.0284	5	"	100	.0311	"
"	0	.0301	6	"	300	.0338	"
"	75	.0309	"	" fluid	to 310	.0356	30
"	20–100	.0302	7	" "	" 360	.0410	"
" fluid	280–380	.0363	8	"	18–100	.03096	43
Boron	0–100	.307	9	"	16–256	.03191	"
Bromine, solid	—78––20	.0843	10	Lithium	—100	.5997	31
" fluid	13–45	.107	11	"	0	.7951	"
Cadmium	21	.0551	2	"	50	.9063	"
"	100	.0570	"	"	100	1.0407	"
"	200	.0594	"	"	190	1.3745	"
"	300	.0617	"	Magnesium	—185–+20	0.222	4
Cæsium	0–26	.0482	12	"	60	.2492	7
Calcium	—185–+20	.157	4	"	325	.3235	"
"	0–181	.170	13	"	625	.4352	"
Carbon, graphite	—50	.114	14	"	20–100	.2492	"
" "	+11	.160	"	Manganese	60	.1211	"
" "	977	.467	"	"	325	.1783	"
" diamond	—50	.0635	"	"	20–100	.1211	"
" "	+11	.113	"	"	—100	.0979	31
" "	985	.459	"	"	0	.1072	"
Cerium	0–100	.0448	15	"	100	.1143	"
Chlorine, liquid	0–24	.2262	16	Mercury	—185–+20	.032	4
Chromium	—200	.0666	17	"	0	.03346	32
"	0	.1039	"	"	85	.0328	"
"	100	.1121	"	"	100	.03284	2
"	600	.1872	"	"	250	.03212	"
"	—185–+20	.086	4	Molybdenum	—185–+20	.062	4
Cobalt	500	.1452	18	"	60	.0647	7
"	1000	.204	"	"	475	.0750	"
"	—182–+15	.0822	19	"	20–100	.0647	"
"	15–100	.1030	"	Nickel	—185–+20	.092	4
Copper	17	.0924	2	"	100	.1128	18
"	100	.0942	"	"	300	.1403	"
"	15–238	.09510	43	"	500	.1299	"
"	900	.1259	20	"	1000	.1608	"
"	—181–+13	.0868	21	"	18–100	.109	26
"	23–100	.0940	"	Osmium	19–98	.0311	10
Gallium, liquid	to 113	.080	22	Palladium	—186–+18	.0528	26
" solid	12–23	.079	22	"	0–100	.0592	24
Germanium	0–100	.0737	23	"	0–1265	.0714	"
Gold	—185–+20	.033	4	Phosphorus, red	0–51	.1829	33
"	0–100	.0316	24	" yellow	13–36	.202	"
Indium	0–100	.0570	13	" "	—186–+20	.178	4

See opposite page for References. See Table 260 for supplementary data.

* Where one temperature alone is given, the "true" specific heat is given; otherwise, the "mean" specific heat.

TABLE 258. — Specific Heat of the Chemical Elements (*continued*).

Element.	Range * of Temperature, °C.	Specific Heat.	Reference.	Element.	Range * of Temperature, °C.	Specific Heat.	Reference.
Platinum	−186–+18	0.0293	26	Sulphur	−188–+18	0.137	36
"	0–100	.0323	24	" rhombic	0–54	.1728	33
"	100	.0275	34	" monoclin.	0–52	.1809	"
"	500	.0356	35	" liquid	119–147	.235	2
"	700	.0368	"	Tantalum	−185–+20	.033	4
"	900	.0380	"	"	1400	0.043	–
"	1100	.0390	"	Tellurium	−188–+18	.047	36
"	1500	.0407	"	" crys.	15–100	.0483	37
"	500	.0335	"	Thallium	−185–+20	.038	4
"	1100	.0358	"	"	20–100	.0326	27
"	1500	.0368	"	Thorium	0–100	.0276	38
Potassium	−185–+20	.170	4	Tin	−196–−79	.0486	26
Rhodium	10–97	.0580	25	"	−76–+18	.0518	"
Ruthenium	0–100	.0611	13	" cast	21–109	.0551	30
Selenium	−188–+18	.068	36	" fluid	250	.05799	18
Silicon	−185–+20	.123	4	" "	1100	.0758	"
"	−39.8	.1360	14	Titanium	−185–+20	.082	4
"	+57.1	.1833	"	"	0–100	.1125	39
"	232	.2029	"	Tungsten	−185–+20	.036	4
Silver	−186–−79	.0496	26	"	0–100	.0336	40
"	−79–+18	.0544	"	"	1000	0.044	–
"	0–100	.0559	13	Uranium	0–98	.028	41
"	23	.05498	2	Vanadium	0–100	.1153	40
"	100	.05663	"	Zinc	−192–+20	.0836	27
"	500	.0581	34	"	20–100	.0931	"
"	17–507	.05987	43	"	0–100	.0935	13
"	800	.076	18	"	100	.0951	2
" fluid	907–1100	.0748	"	"	300	.1040	"
Sodium	−185–+20	.253	4	Zirconium	0–100	.0660	42

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* When one temperature alone is given, the "true" specific heat is given; otherwise, the "mean" specific heat.

Compiled in part from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 259. — Specific Heat of Water and of Mercury.

Specific Heat of Water.							Specific Heat of Mercury.			
Temperature, °C.	Barnes.	Rowland.	Barnes-Regnault.	Temperature, °C.	Barnes.	Barnes-Regnault.	Temperature, °C.	Specific Heat.	Temperature, °C.	Specific Heat.
−5	1.0155	–	–	60	0.9988	0.9994	0	0.03346	90	0.03277
0	1.0091	1.0070	1.0094	65	.9994	1.0004	5	.03340	100	.03269
+5	1.0050	1.0039	1.0053	70	1.0001	1.0015	10	.03335	110	.03262
10	1.0020	1.0016	1.0023	80	1.0014	1.0042	15	.03330	120	.03255
15	1.0000	1.0000	1.0003	90	1.0028	1.0070	20	.03325	130	.03248
20	0.9987	.9991	0.9990	100	1.0043	1.0101	25	.03320	140	.03241
25	.9978	.9989	.9981	120	–	1.0162	30	.03316	150	.0324
30	.9973	.9990	.9976	140		1.0223	35	.03312	170	.0322
35	.9971	.9997	.9974	160		1.0285	40	.03308	190	.0320
40	.9971	1.0006	.9974	180	–	1.0348	50	.03300	210	.0319
45	.9973	1.0018	.9976	200		1.0410	60	.03294	–	–
50	.9977	1.0031	.9980	220		1.0476	70	.03289		
55	.9982	1.0045	.9985	–		–	80	.03284	–	

Barnes's results: Phil. Trans. (A) 199, 1902; Phys. Rev. 15, 1902; 16, 1903. (H thermometer.)
Bousfield, Phil. Trans. A 211, p. 199, 1911. Barnes-Regnault's as revised by Peabody; Steam Tables.

The mercury data from 0° C to 80, Barnes-Cooke (H thermometer); from 90° to 140, mean of Winklemann, Naccari and Milthaler (air thermometer); above 140°, mean of Naccari and Milthaler.

TABLE 260. — Additional Specific Heats of the Chemical Elements.

Element.	Temperature.	Sp. Heat.	Reference.	Element.	Temperature.	Sp. Heat.	Reference.
Aluminum .	—240.6°	0.0092	1	Lithium . .	—191-—80	0.521	2
	—190.0	.0889	"		—78-0	.595	"
	—190-—82	.1466	2		—75-+19	.629	"
	—76-—1	.1962	"	Manganese .	—188-—79	.0820	4
	+16-+100	.2122	3		—79-+15	.1091	"
	+16-+304	.2250	"	Mercury, sol.	—77-—42	.0329	2
Boron . . .	—191-—78	.0707	2	" liq.	—36-—3	.0334	"
	—76-0	.1677	"	Potassium .	—191-—80	.1568	"
Bromine . .	—192-—80	.0702	4		—78-0	.1666	2
Carbon, graph.	—191-—79	.0573	2	Sodium . .	—191-—83	.243	"
	—76-0	.1255	"		—77-0	.276	"
—Ache. graph.	—244.0	.005	6	Zinc . . .	—190-—82	.0792	"
	—186.0	.027	"		—76-2	.0906	"
—Diamond .	—79-—3	.0720	2	Iron . . .	0-+200°	.1175	5
Copper . .	—249.5	.0035	1		0-+300	.1233	"
	—185.0	.0532	"		0-+400	.1282	"
	—190-—83	.0720	2		0-+500	.1338	"
	—76-0	.0878	"		0-+600	.1396	"
	+15-+238	.0951	3		0-+700	.1487	"
Iodine . . .	—90-+17	.0485	4		0-+800	.1597	"
	—191-—80	.0454	"		0-+900	.1644	"
Lead . . .	—77-—3	.0303	2		0-+1000	.1557	"
	+18-+100	.0310	3		0-+1100	.1534	"
	+16-+256	.0319	"				

1. Nernst, Lindemann, 1910, 1911.
2. Kosef, Ann. der Phys. 36, 1911.
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TABLE 261. — Mean Specific Heats of Quartz, Silica Glass, and Platinum from zero, C., to the temperature named.

The mean specific heats of quartz above 550° are here increased by the heat (2.3 calories) of the inversion at 575°. The accuracy is probably better than 2 per mille.

Interval.	Quartz.	Silica Glass.	Platinum.	Obs.—calculated for Pt.
0-100°	.1870	.1845	—	—
0-300°	.2169	.2124	.03283	.00000
0-500°	.2382	.2303	.03363	+.00012
0-550°	.2441	—	—	—
0-600°	.2520	—	—	—
0-700°	.2555	.2433	.03424	+.00005
0-900°	.2608	.2523	.03487	.00000
0-1100°	.2654	—	.03551	—.00004
0-1300°	—	—	.03620	—.00003

The results for Platinum follow the formula :

Sp. Heat = .03174 + .000 0034 θ very closely. If the formula were strictly correct the *true specific heat* at any temp. would be : .03174 +.000 006 8 θ, which is probably true to 1% as it is.

Determinations by W. P. White. Geographical Laboratory.

TABLE 262. — Specific Heat of Various Solids.*

Solid.	Temperature °C.	Specific Heat.	Authority.†
Alloys:			
Bell metal	15–98	0.0858	R
Brass, red	0	.08991	L
" yellow	0	.08831	"
80 Cu+20 Sn	14–98	.0862	R
88.7 Cu+11.3 Al	20–100	.10432	Ln
German silver	0–100	.09464	T
Lipowitz alloy: 24.97 Pb + 10.13 Cd + 50.66 Bi +14.24 Sn	5–50	.0345	M
" "	100–150	.0426	"
Rose's alloy: 27.5 Pb+48.9 Bi+23.6 Sn	−77–20	.0356	S
" "	20–89	.0552	"
Wood's alloy: 25.85 Pb + 6.99 Cd + 52.43 Bi + 14.73 Sn	5–50	.0352	M
" " (fluid)	100–150	.0426	"
Miscellaneous alloys:			
17.5 Sb+29.9 Bi+18.7 Zn+33.9 Sn	20–99	.05657	R
37.1 Sb+62.9 Pb	10–98	.03880	"
39.9 Pb+60.1 Bi	16–99	.03165	P
" " (fluid)	144–358	.03500	"
63.7 Pb+36.3 Sn	12–99	.04073	R
46.7 Pb+53.3 Sn	10–99	.04507	"
63.8 Bi+36.2 Sn	20–99	.04001	"
46.9 Bi+53.1 Sn	20–99	.04504	"
Gas coal	20–1040	.3145	–
Glass, normal thermometer 16^{III}	19–100	.1988	W
" French hard thermometer	–	.1869	Z
" crown	10–50	.161	H M
" flint	10–50	.117	"
Ice	−188– −252	.146	D
"	−78– −188	.285	"
"	−18– −78	.463	"
India rubber (Para)	? –100	.481	G-T
Paraffin	−20– +3	.3768	R W
"	−19– +20	.5251	"
"	0–20	.6939	"
"	35–40	.622	B
" fluid	60–63	.712	"
Vulcanite	20–100	.3312	A M

TABLE 263. — Specific Heat of Various Liquids.*

Liquid.	Temperature °C.	Specific Heat.	Authority.†	Liquid.	Temperature °C.	Specific Heat.	Authority.†
Alcohol, ethyl	−20	0.5053	R	Nitrobenzole	28	0.362	A
" "	0	.548	"	Napthalene, $C_{10}H_8$	80–85	.396	B
" "	40	.648	"	"	90–95	.409	"
" methyl	5–10	.590	"	Oils: castor	–	.434	W
" "	15–20	.601	"	citron	5.4	.438	H W
Anilin	15	.514	G	olive	6.6	.471	"
"	30	.520	"	sesame	–	.387	W
"	50	.529	"	turpentine	0	.411	R
Benzole, C_6H_6	10	.340	H-D	Petroleum	21–58	.511	Pa
"	40	.423	"	Toluol, C_6H_8	10	.364	H-D
"	65	.482	"	"	65	.490	"
Diphenylamine, $C_{12}H_{11}N$	53	.464	B	"	85	.534	"
"	65	.482	"	$CaCl_2$, sp. gr. 1.14	−15	.764	DMG
Ethyl ether	0	.529	R	" " "	0	.775	"
Glycerine	15–50	.576	E	" " "	+20	.787	"
Nitrobenzole	14	.350	A	" " 1.20	−20	.695	"

* These specific heat tables are compiled partly from more extended tables in Landolt-Börnstein-Meyerhoffer's Tables.
† For references see Table 263, page 242.

TABLE 263. — Specific Heat of Various Liquids.

Liquid.	Temperature °C.	Specific Heat.	Authority.	Liquid.	Temperature °C.	Specific Heat.	Authority.
$CaCl_2$, sp. gr. 1.20	0	0.712	DMG	$KOH + 30\ H_2O$	18	0.876	TH
" " "	+20	.725	"	" + 100 "	18	.975	"
" " 1.26	−20	.651	"	$NaOH + 50\ H_2O$	18	.942	"
" " "	0	.663	"	" + 100 "	18	.983	"
" " "	+20	.676	"	$NaCl + 10\ H_2O$	18	.791	"
$CuSo_4 + 50\ H_2O$	12–15	.848	Pa	" + 200 "	18	.978	"
" +200 "	12–14	.951	"	Sea water, sp. gr. 1.0043	17.5	.980	"
" +400 "	13–17	.975	"	" " " 1.0235	17.5	.938	"
$ZnSO_4 + 50\ H_2O$	20–52	.842	Ma	" " " 1.0463	17.5	.903	"
" +200 "	20–52	.952	"				

A, Abbot.
AM, A. M. Mayer.
B, Batelli.
D, Dewar.
E, Emo.
G, Griffiths.
G-T, Gee and Terry.
DMG, Dickinson, Mueller, and George.
H-D, de Heen and Deruyts.
HM, H. Meyer.
L, Lorenz.
Ln, Luginen.
M, Mazotto.
Ma, Marignac.
P, Person.
Pa, Pagliani.
R, Regnault.
RW, R. W. Weber.
T, Tomlison.
S, Schüz.
Th, Thomsen.
W, Wachsmuth.
Wn, Winkelmann.
Z, Zouloff.

TABLE 264. — Specific Heat of Minerals and Rocks.

Substance.	Temperature ° C.	Specific Heat.	Reference.	Substance.	Temperature ° C.	Specific Heat.	Reference.
Andalusite	0–100	0.1684	1	Rock-salt	13–45	0.219	6
Anhydrite, $CaSO_4$	0–100	.1753	1	Serpentine	16–98	.2586	2
Apatite	15–99	.1903	2	Siderite	9–98	.1934	4
Asbestos	20–98	.195	3	Spinel	15–47	.194	6
Augite	20–98	.1931	3	Talc	20–98	.2092	3
Barite, $BaSO_4$	10–98	.1128	4	Topaz	0–100	.2097	1
Beryl	15–99	.1979	2	Wollastonite	19–51	.178	6
Borax, $Na_2B_4O_7$ fused	16–98	.2382	4	Zinc blende, ZnS	0–100	.1146	1
Calcspar, $CaCO_3$	0–50	.1877	1	Zircon	21–51	.132	6
" "	0–100	.2005	1	Rocks:			
" "	0–300	.2204	1	Basalt, fine, black	12–100	.1996	6
Casiderite, SnO_3	16–98	.0933	4	" " "	20–470	.199	9
Corundum	9–98	.1976	4	" " "	470–750	.243	9
Cryolite, $Al_2Fl_6.6NaF$	16–99	.2522	2	" " "	750–880	.626	9
Fluorite, CaF_2	15–99	.2154	4	" " "	880–1190	.323	9
Galena, PbS	0–100	.0466	5	Dolomite	20–98	.222	3
Garnet	16–100	.1758	2	Gneiss	17–99	.196	10
Hematite, Fe_2O_3	15–99	.1645	2	"	17–213	.214	10
Hornblende	20–98	.1952	3	Granite	12–100	.192	7
Hypersthene	20–98	.1914	3	Kaolin	20–98	.224	3
Labradorite	20–98	.1949	3	Lava, Aetna	23–100	.201	11
Magnetite	18–45	.156	6	" "	31–776	.259	11
Malachite, $Cu_2CO_4.H_2O$	15–99	.1763	2	" Kilauea	25–100	.197	11
Mica (Mg)	20–98	.2061	3	Limestone	15–100	.216	12
" (K)	20–98	.2080	3	Marble	0–100	.21	–
Oligoclase	20–98	.2048	3	Quartz sand	20–98	.191	3
Orthoclase	15–99	.1877	2	Sandstone	–	.22	–
Pyrites, copper	15–99	.1291	2				
Pyrolusite, MnO_2	17–48	.159	6				
Quartz, SiO_2	12–100	.188	7				
" "	0	.1737	8				
" "	350	.2786	8				
" "	400–1200	.305	8				

1 Lindner.
2 Oeberg.
3 Ulrich.
4 Regnault.
5 Tilden.
6 Kopp.
7 Joly.
8 Pionchon.
9 Roberts-Austen, Rücker.
10 R. Weber.
11 Bartoli.
12 Morano.

Compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

Table 265.

SPECIFIC HEATS OF GASES AND VAPORS.

Substance.	Range of Temp. °C.	Sp. Ht. Constant Pressure.	Authority.	Range of Temp. °C.	Mean Ratio of Specific Heats. C_p/C_v.	Authority.
Acetone, C_3H_6O	26–110	0.3468	Wiedemann.			
" "	27–179	0.3740	"			
" "	129–233	0.4125	Regnault.			
Air	—30–+10	0.2377	"	5–14	1.4025	Lummer and Pringsheim.
"	0–100	0.2374	"			
"	0–200	0.2375	"			
"	20–440	0.2366	Holborn and			
"	20–630	0.2429	Austin.			
"	20–800	0.2430	"			
Alcohol, C_2H_5OH	108–220	0.4534	Regnault.	53	1.133	Jaeger.
" "	–	–	–	100	1.134	Stevens.
" C_2H_3OH	101–223	0.4580	Regnault.	100	1.256	"
Ammonia	23–100	0.5202	Wiedemann.	0	1.3172	Wüllner.
"	27–200	0.5356	"	100	1.2770	"
"	24–216	0.5125	Regnault.			
Argon	20–90	0.1233	Dittenberger.	0	1.667	Niemeyer.
Benzole, C_6H_6	34–115	0.2990	Wiedemann.	20	1.403	Pagliani.
" "	35–180	0.3325	"	60	1.403	"
" "	116–218	0.3754	Regnault.	99.7	1.105	Stevens
Bromine	83–228	0.0555	"	20–388	1.293	Strecker.
"	19–388	0.0553	Strecker.			
Carbon dioxide, CO_2	—28–+7	0.1843	Regnault.	4–11	1.2995	Lummer and Pringsheim.
" " "	15–100	0.2025	"			
" " "	11–214	0.2169	"			
" monoxide, CO	23–99	0.2425	Wiedemann.	0	1.403	Wüllner.
" " "	26–198	0.2426	"	100	1.395	"
" disulphide, CS_2	86–190	0.1596	Regnault.	3–67	1.205	Beyme.
Chlorine	13–202	0.1241	"	20–340	1.323	Strecker.
"	16–343	0.1125	Strecker.	0	1.336	Martini.
Chloroform, $CHCl_3$	27–118	0.1441	Wiedemann.	22–78	1.102	Beyme.
" "	28–189	0.1489	"	99.8	1.150	Stevens.
Ether, $C_4H_{10}O$	69–224	0.4797	Regnault.	3–46	1.025	Beyme.
" "	27–189	0.4618	Wiedemann.	42–45	1.029	Müller.
" "	25–111	0.4280	"	12–20	1.024	Low.
Hydrochloric acid, HCl	13–100	0.1940	Strecker.	20	1.389	Strecker.
" " "	22–214	0.1867	Regnault.	100	1.400	"
Hydrogen	—28–+9	3.3996	"	4–16	1.4080	Lummer and Pringsheim.
"	12–198	3.4090	"			
"	21–100	3.4100	Wiedemann.			
" sulphide, H_2S	20–206	0.2451	Regnault.	10–40	1.276	Müller.
Methane, CH_4	18–208	0.5929	"	11–30	1.316	"
Nitrogen	0–200	0.2438	"	–	1.41	Cazin.
"	20–440	0.2419	Holborn and			
"	20–630	0.2464	Austin.			
"	20–800	0.2497	"			
Nitric oxide, NO	13–172	0.2317	Regnault.			
Nitrogen tetroxide, NO_2	27–67	1.625	Berthelot and	-	1.31	Natanson.
" " "	27–150	1.115	Olger.			
" " "	27–280	0.65	"			
Nitrous oxide, N_2O	16–207	0.2262	Regnault.	0	1.311	Wüllner.
" " "	26–103	0.2126	Wiedemann.	100	1.272	"
" " "	27–206	0.2241	"			
Oxygen	13–207	0.2175	Regnault.	5–14	1.3977	Lummer and Pringsheim.
"	20–440	0.2240	Holborn and			
"	20–630	0.2300	Austin.			
Sulphur dioxide, SO_2	16–202	0.1544	Regnault.	16–34	1.256	Müller.
Water vapor, H_2O	0	0.4655	Thiesen.	78	1.274	Beyme.
" " "	100	0.421	"	94	1.33	Jaeger.
" " "	180	0.51	"			

THERMOMETERS.

TABLE 266. — Gas and Mercury Thermometers.

If t_H, t_N, t_{CO_2}, t_{16}, t_{59}, t_T, are temperatures measured with the hydrogen, nitrogen, carbonic acid, 16^{III}, 59^{III}, and "verre dur" (Tonnelot), respectively, then

$$t_H - t_T = \frac{(100-t)t}{100^2}[-0.61859 + 0.0047351.t - 0.000011577.t^2]^*$$

$$t_N - t_T = \frac{(100-t)t}{100^2}[-0.55541 + 0.0048240.t - 0.000024807.t^2]^*$$

$$t_{CO_2} - t_T = \frac{(100-t)t}{100^2}[-0.33386 + 0.0039910.t - 0.000016678.t^2]^*$$

$$t_H - t_{16} = \frac{(100-t)t}{100^2}[-0.67039 + 0.0047351.t - 0.000011577.t^2]^\dagger$$

$$t_H - t_{59} = \frac{(100-t)t}{100^2}[-0.31089 + 0.0047351.t - 0.000011577.t^2]^\dagger$$

* Chappuis; Trav. et Mém. du Bur. internat. des Poids et Mes. 6, 1888.
† Thiesen, Scheel, Sell; Wiss. Abh. d. Phys. Techn. Reichanstalt, 2, 1895; Scheel; Wied. Ann. 58, 1896; D. Mech. Ztg. 1897.

TABLE 267. $t_H - t_{16}$ (Hydrogen — 16^{III}).

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.000°	—.007°	—.013°	—.019°	—.025°	—.031°	—.036°	—.042°	—.047°	—.051°
10	—.056	—.061	—.065	—.069	—.073	—.077	—.080	—.084	—.087	—.090
20	—.093	—.096	—.098	—.101	—.103	—.105	—.107	—.109	—.110	—.112
30	—.113	—.114	—.115	—.116	—.117	—.118	—.119	—.119	—.119	—.120
40	—.120	—.120	—.120	—.120	—.119	—.119	—.118	—.118	—.117	—.116
50	—.116	—.115	—.114	—.113	—.111	—.110	—.109	—.107	—.106	—.104
60	—.103	—.101	—.099	—.097	—.096	—.094	—.092	—.090	—.087	—.085
70	—.083	—.081	—.078	—.076	—.074	—.071	—.069	—.066	—.064	—.061
80	—.058	—.056	—.053	—.050	—.048	—.045	—.042	—.039	—.036	—.033
90	—.030	—.027	—.024	—.021	—.018	—.015	—.012	—.009	—.006	—.003
100	.000									

TABLE 266. $t_H - t_{59}$ (Hydrogen — 59^{III}).

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.000°	—.003°	—.006°	—.009°	—.011°	—.014°	—.016°	—.018°	—.020°	—.022°
10	—.024	—.025	—.027	—.028	—.030	—.031	—.032	—.033	—.034	—.035
20	—.035	—.036	—.036	—.037	—.037	—.037	—.038	—.038	—.038	—.038
30	—.038	—.037	—.037	—.037	—.037	—.036	—.036	—.035	—.035	—.034
40	—.034	—.033	—.032	—.032	—.031	—.030	—.029	—.028	—.028	—.027
50	—.026	—.025	—.024	—.023	—.022	—.021	—.020	—.019	—.018	—.017
60	—.016	—.015	—.015	—.014	—.013	—.012	—.011	—.010	—.009	—.008
70	—.008	—.007	—.006	—.005	—.005	—.004	—.003	—.003	—.002	—.001
80	—.001	—.001	.000	.000	+.001	+.001	+.001	+.002	+.002	+.002
90	+.002	+.002	+.002	+.002	+.002	+.002	+.001	+.001	+.001	.000
100	.000									

TABLE 269. (Hydrogen — 16^{III}), (Hydrogen — 59^{III}).

	—5°	—10°	—15°	—20°	—25°	—30°	—35°
$t_H - t_{16}$	+0.04°	+0.08°	+0.13°	+0.19°	+0.25°	+0.32°	+0.40°
$t_H - t_{59}$	+0.02°	+0.04°	+0.07°	+0.10°	+0.14°	+0.18°	+0.23°

All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

AIR AND MERCURY THERMOMETERS.

TABLE 270. $t_{AIR} - t_{16}$. (Air — 16^{III}.)

°C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0	.000	−.006	−.012	−.017	−.022	−.027	−.032	−.037	−.041	−.045
10	−.049	−.053	−.057	−.061	−.065	−.068	−.071	−.074	−.077	−.080
20	−.083	−.086	−.089	−.091	−.093	−.095	−.097	−.099	−.101	−.102
30	−.103	−.104	−.105	−.106	−.107	−.108	−.109	−.110	−.110	−.110
40	−.110	−.110	−.111	−.111	−.110	−.110	−.110	−.109	−.109	−.108
50	−.107	−.107	−.106	−.105	−.104	−.103	−.102	−.101	−.100	−.098
60	−.096	−.095	−.093	−.092	−.090	−.088	−.086	−.084	−.082	−.080
70	−.078	−.076	−.074	−.072	−.070	−.067	−.065	−.062	−.060	−.057
80	−.054	−.052	−.049	−.047	−.044	−.041	−.039	−.036	−.034	−.031
90	−.028	−.025	−.023	−.020	−.017	−.014	−.011	−.009	−.006	−.003
100	.000	+.003	+.006	+.008	+.011	+.014	+.017	+.019	+.022	+.025
110	+.028	+.030	+.033	+.035	+.038	+.041	+.043	+.046	+.048	+.050
120	+.053	+.055	+.057	+.060	+.062	+.064	+.066	+.068	+.070	+.072
130	+.074	+.076	+.078	+.080	+.081	+.083	+.084	+.086	+.087	+.089
140	+.090	+.091	+.092	+.093	+.094	+.095	+.096	+.096	+.097	+.097
150	+.098	+.098	+.098	+.099	+.099	+.099	+.098	+.098	+.098	+.097
160	+.097	+.096	+.095	+.094	+.093	+.092	+.090	+.089	+.088	+.086
170	+.084	+.082	+.080	+.078	+.076	+.073	+.071	+.068	+.065	+.062
180	+.059	+.055	+.052	+.048	+.045	+.041	+.037	+.033	+.028	+.023
190	+.019	+.014	+.009	+.004	−.001	−.007	−.013	−.019	−.025	−.031
200	−.038	−.045	−.051	−.058	−.066	−.073	−.080	−.088	−.096	−.105
210	−.113	−.122	−.130	−.139	−.148	−.158	−.168	−.177	−.187	−.198
220	−.208	−.219	−.230	−.241	−.252	−.264	−.275	−.287	−.300	−.312
230	−.325	−.338	−.351	−.365	−.378	−.392	−.407	−.421	−.436	−.450
240	−.466	−.481	−.497	−.513	−.529	−.546	−.562	−.579	−.597	−.614
250	−.632	−.650	−.668	−.687	−.706	−.725	−.745	−.765	−.785	−.805
260	−.825	−.846	−.867	−.889	−.911	−.933	−.955	−.978	−1.001	−1.025
270	−1.048	−1.072	−1.096	−1.121	−1.146	−1.171	−1.196	−1.222	−1.248	−1.274
280	−1.301	−1.328	−1.356	−1.384	−1.412	−1.440	−1.469	−1.498	−1.528	−1.558
290	−1.588	−1.618	−1.649	−1.680	−1.711	−1.743	−1.776	−1.808	−1.841	−1.874
300	−1.908									

TABLE 271. $t_{AIR} - t_{59}$. (Air — 59^{III}.)

°C.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
100	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
110	.000	.000	.000	−.001	−.001	−.001	−.001	−.001	−.002	−.002
120	−.002	−.002	−.002	−.002	−.002	−.003	−.003	−.003	−.004	−.004
130	−.004	−.004	−.005	−.005	−.006	−.006	−.006	−.007	−.007	−.008
140	−.008	−.008	−.009	−.009	−.010	−.010	−.011	−.011	−.012	−.012
150	−.013	−.013	−.014	−.015	−.016	−.016	−.016	−.017	−.018	−.019
160	−.019	−.020	−.021	−.021	−.022	−.023	−.024	−.025	−.026	−.027
170	−.028	−.029	−.030	−.031	−.032	−.033	−.034	−.035	−.037	−.038
180	−.039	−.040	−.041	−.043	−.044	−.045	−.046	−.048	−.049	−.051
190	−.052	−.053	−.055	−.056	−.057	−.059	−.060	−.062	−.064	−.066
200	−.067									

GAS, MERCURY, ALCOHOL, TOLUOL, PETROLETHER, PENTANE, THERMOMETERS.

TABLE 272. — $t^H - t_M$ (Hydrogen-Mercury).

Temperature, C.	Thuringer Glass.*	Verre dur. Tonnelot.†	Resistance Glass.*	English Crystal Glass.*	Choisy-le-Roi.*	122^III.*	Nitrogen Thermometer. $T_H - T_N$.†	CO_2 Thermometer. $T_H - T_{CO_2}$.†
°	°	°	°	°	°	°	°	°
0	.000	.000	.000	.000	.000	.000	.000	.000
10	—.075	—.052	—.066	—.008	—.007	—.005	—.006	—.025
20	—.125	—.085	—.108	—.001	—.004	—.006	—.010	—.043
30	—.156	—.102	—.131	+.017	+.004	—.002	—.011	—.054
40	—.168	—.107	—.140	+.037	+.014	+.001	—.011	—.059
50	—.166	—.103	—.135	+.057	+.025	+.004	—.009	—.059
60	—.150	—.090	—.119	+.073	+.033	+.008	—.005	—.053
70	—.124	—.072	—.095	+.079	+.037	+.009	—.001	—.044
80	—.088	—.050	—.068	+.070	+.032	+.007	+.002	—.031
90	—.047	—.026	—.034	+.046	+.022	+.006	+.003	—.016
100	.000	.000	.000	.000	.000	.000	.000	.000

* Schlösser, Zt. Instrkde. 21, 1901. † Chappuis, Trav. et mém. du Bur. Intern. des Poids et Mes. 6, 1888.

TABLE 273. — Comparison of Air and High Temperature Mercury Thermometers.

Comparison of the air thermometer with the high temperature mercury thermometer, filled under pressure and made of 59^{III} glass.

Air.	59^{III}.	Air.	59^{III}.
°	°	°	°
0	0.	375	385.4
100	100.	400	412.3
200	200.4	425	440.7
300	304.1	450	469.1
325	330.9	475	498.0
350	358.1	500	527.8

Mahlke, Wied. Ann. 1894.

TABLE 274. — Comparison of Hydrogen and Other Thermometers.

Comparison of the hydrogen thermometer with the toluol, alcohol, petrolether, and pentane thermometers (verre dur).

Hydrogen.	Toluol.*	Alcohol I.*	Alcohol II.*	Petrolether.†	Pentane.‡
°	°	°	°	°	°
0	0.00	0.00	0.00	-	0.00
—10	—8.54	—9.31	—9.44	-	—9.03
—20	—16.90	—18.45	—18.71	-	—17.87
—30	—25.10	—27.44	—27.84	-	—26.55
—40	—33.15	—36.30	—36.84	-	—35.04
—50	—41.08	—45.05	—45.74	—42.6	—43.36
—60	—48.90	—53.71	—54.55	-	—51.50
—70	—56.63	—62.31	—63.31	-	—59.46
—100	-	-	-	—80.2	—82.28
—150	-	-	-	—113.0	—116.87
—200	-	-	-	—140.7	—146.84

* Chappuis, Arch. sc. phys. (3) 18, 1892. † Holhorn, Ann. d. Phys. (4) 6, 1901. ‡ Rothe, unpublished.
All compiled from Landolt-Börnstein-Meyerhoffer's Physikalisch-chemische Tabellen.

TABLE 275. — Platinum Resistance Thermometers.

Callendar has shown that if we define the platinum temperature, pt, by pt $= 100 \{ (R - R_0)/(R_{100} - R_0) \}$, where R is the observed resistance at t° C., R_0 that at 0°, R_{100} at 100°, then the relation between the platinum temperature and the temperature t on the scale of the gas thermometer is represented by $t - pt = \delta \{ t/100 - 1 \} t/100$ where δ is a constant for any given sample of platinum and about 1.50 for pure platinum (impure platinum having higher values). This holds good between —23° and 450° when δ has been determined by the boiling point of sulphur (445°.)

See Waidner and Burgess, Bul. Bureau Standards, 6, p. 149, 1909.

TABLE 276. — Thermodynamic Temperature of the Ice Point, and Reduction to Thermodynamic Scale.

Mean = 273.10° C. (ice point)

For a discussion of the various values and for the corrections of the various gas thermometers to the thermodynamic scale see Buckingham, Bull. Bureau Standards, 3, p. 237, 1907.

Scale Corrections for Gas Thermometers.

Temp. C.	Constant pressure = 76 cm.			Constant volume Θ_0 = 273.10 C.		
	He	H	N	He	H	N
—250°	—	—	—	+0.02	—	—
—200	+0.10	+0.26	—	+0.01	+0.06	—
—100	+ .03	+0.03	+0.33	.000	+ .014	+0.07
— 50	+ .009	+0.004	+ .09	.000	+ .004	+ .02
+ 25	— .002	— .002	— .013	.000	.000	— .006
+ 50	— .002	— .003	— .017	.000	.000	— .006
+ 75	— .002	— .002	— .012	.000	.000	— .004
+150	+ .005	+ .003	+ .04	.000	+ .001	+ .01
+200	+ .01	+ .01	+ .10	.000	+ .002	+ .04
+450	+ .07	+ .04	+ .50	0.00	+ .01	+ .15
+1000	+ .24	+ .01	+1.7	—	+0.04	+ .70
+1500	—	—	+3.0	—	—	+1.3

See Burgess, The Present Status of the Temperature Scale, Chemical News, 107, p. 169, 1913.

TABLE 277. — Standard Points for the Calibration of Thermometers.

Substance.	Point.	Atmosphere.	Crucible.	Temperatures. °C.	Temperatures. Thermodynamic.
Water	boiling, 760 mm.	air	-	100.00	100.00
Napthalene	" " "	"	-	218.0	218.0
Benzophenone	" " "	-	-	305.85 ± 0.1	305.9
Cadmium	melting or solidify.	air	graphite	320.8 ± 0.2	320.9
Zinc	" " "	"	"	419.3 ± 0.3	419.4
Sulphur	boiling, 760 mm.	-	-	444.45 ± 0.1	444.55
Antimony	melting or solidify.	CO_2	graphite	629.8 ± 0.5	630.0
Aluminum	solidification	"	"	658.5 ± 0.6	658.7
Silver	melting or solidify.	"	"	960.0 ± 0.7	
Gold	" " "	"	"	1062.4 ± 0.8	
Copper	" " "	"	"	1082.6 ± 0.8	
Li_2SiO_3	melting	air	platinum	1201.0 ± 1.0	
Diopside, pure	"	"	"	1391.2 ± 1.5	
Nickel	melting or solidify.	H and N	magnesia and Mg. aluminate	1452.3 ± 2.0	
Cobalt	" " "	"	magnesia	1489.8 ± 2.0	
Palladium	" " "	air	"	1549.2 ± 2.0	
Anorthite, pure	melting	"	platinum	1549.5 ± 2.0	
Platinum	"	"		1752. ± 5.*	
				1755. ± 5.†	

* Thermoelectric extrapolation. † Optical extrapolation.

(Day and Sosman, Journal de Physique, 1912. Mesure des témperatures élevées.) A few additional points are: H, boils — 252.7°; O, boils — 182.9°; Hg. freezes — 37.7°; Alumina melts 2000°; Tungsten melts 3000°.

CORRECTION FOR TEMPERATURE OF MERCURY IN THERMOMETER STEM.

The Stem Correction is proportional to $n\beta(T-t)$: where n is the number of degrees in the exposed stem; β is the apparent coefficient of expansion of mercury in the glass; T is the measured temperature; and t is the mean temperature of the exposed stem determined by another thermometer, exposed some 10 cm. from, and at about half the height of, the exposed stem of the first.

For temperatures up to 100°C, the value of β is for:

Jena glass XVI^{III} or Greiner and Friedrich resistance glass, $\frac{1}{6300}$ or 0.000159;

Jena glass 59^{III}, $\frac{1}{6100}$ or 0.000164.

At 100° the correction is in round numbers 0.01° for each degree of the exposed stem; at 200° 0.02°; and for higher temperatures proportionately greater. At 500° it may amount to 0.07° for each exposed degree.

Tables 278–280 are taken from Rimbach, Zeitschrift für Instrumentenkunde, 10, 153, 1890, and apply to thermometers of Jena or of resistance glass.

TABLE 278. — Stem Correction for Thermometer of Jena Glass (0°–360° C.).

Degree length 0.9 to 1.1 mm; t = the observed temperature; t' = that of the surrounding air 1 dm. away; n = the length of the exposed thread.

Correction to be added to the Reading t.										
n	$t-t'$									
	70°	80°	90°	100°	120°	140°	160°	180°	200°	220°
10	0.01	0.01	0.03	0.04	0.07	0.10	0.13	0.17	0.19	0.21
20	0.08	0.12	0.14	0.19	0.25	0.28	0.32	0.40	0.49	0.54
30	0.25	0.28	0.32	0.36	0.42	0.48	0.54	0.66	0.78	0.87
40	0.30	0.35	0.41	0.48	0.60	0.67	0.77	0.92	1.08	1.20
50	0.41	0.46	0.52	0.59	0.79	0.89	0.98	1.16	1.38	1.53
60	0.52	0.60	0.68	0.79	0.99	1.11	1.23	1.46	1.70	1.87
70	0.63	0.74	0.85	0.98	1.20	1.32	1.45	1.70	1.99	2.21
80	0.75	0.87	1.01	1.15	1.38	1.53	1.70	1.98	2.29	2.54
90	0.87	0.99	1.13	1.28	1.62	1.82	1.94	1.25	2.60	2.89
100	0.98	1.12	1.29	1.47	1.82	2.03	2.20	2.55	2.92	3.24
120	–	–	–	1.88	2.28	2.49	2.68	3.13	3.59	3.96
140	–	–	–	–	2.75	2.97	3.22	3.75	4.24	4.69
160	–	–	–	–	–	3.35	3.80	4.35	4.92	5.45
180	–	–	–	–	–	–	4.37	4.99	5.63	6.22
200	–	–		–	–	–	–	5.68	6.34	6.98
220	–	–		–	–	–	–	–	7.05	7.82

See "The correction for Emergent Stem of Mercurial Thermometer." Buckingham, Bul. Bur. of Standards, 8, p. 239, 1912.

CORRECTION FOR TEMPERATURE OF MERCURY IN THERMOMETER STEM (*continued*).

TABLE 279. — Stem Correction for Thermometer of Jena Glass (0°-360° C).

Degree length 1 to 1.6 mm.; t = the observed temperature; t' = that of the surrounding air one dm. away; n = the length of the exposed thread.

Correction to be added to Thermometer Reading.*											
n	$t - t'$										n
	70°	80°	90°	100°	120°	140°	160°	180°	200°	220°	
10°	0.02	0.03	0.05	0.07	0.11	0.17	0.21	0.27	0.33	0.38	**10°**
20	0.13	0.15	0.18	0.22	0.29	0.38	0.46	0.53	0.61	0.67	20
30	0.24	0.28	0.33	0.39	0.48	0.59	0.70	0.78	0.88	0.97	30
40	0.35	0.41	0.48	0.56	0.68	0.82	0.94	1.04	1.16	1.28	40
50	0.47	0.53	0.62	0.72	0.88	1.03	1.17	1.31	1.44	1.59	**50**
60	0.57	0.66	0.77	0.89	1.09	1.25	1.42	1.58	1.74	1.90	60
70	0.69	0.79	0.92	1.06	1.30	1.47	1.67	1.86	2.04	2.23	70
80	0.80	0.91	1.05	1.21	1.52	1.71	1.94	2.15	2.33	2.55	80
90	0.91	1.04	1.19	1.38	1.73	1.96	2.20	2.42	2.64	2.89	**90**
100	1.02	1.18	1.35	1.56	1.97	2.18	2.45	2.70	2.94	3.23	100
110	–	–	–	1.78	2.19	2.43	2.70	2.98	3.26	3.57	110
120	–	–	–	1.98	2.43	2.69	2.95	3.26	3.58	3.92	120
130	–	–	–	–	2.68	2.94	3.20	3.56	3.89	4.28	**130**
140	–	–	–	–	2.92	3.22	3.47	3.86	4.22	4.64	140
150	–	–	–	–	–	–	3.74	4.15	4.56	5.01	150
160	–	–	–	–	–	–	4.00	4.46	4.90	5.39	160
170	–		–	–	–	–	4.27	4.76	5.24	5.77	**170**
180	–	–	–	–	–	–	4.54	5.07	5.59	6.15	180
190	–	–	–	–	–	–	–	5.38	5.95	6.54	190
200	–	–		–	–	–	–	5.70	6.30	6.94	200
210	–	–	–	–	–	–	–	–	6.68	7.35	**210**
220	–	–	–	–	–	–	–	–	7.04	7.75	220

* See Hovestadt's "Jena Glass" (translated by J. D. and A. Everett) for data on changes of thermometer zeros.

TABLE 280. — Stem Correction for a so-called Normal Thermometer of Jena Glass (0°-100° C).

Divided into tenth degrees; degree length about 4 mm.

Correction to be added to the Reading t.												
n	$t - t'$											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
10	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.10
20	0.12	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.22	0.23
30	0.21	0.22	0.23	0.24	0.25	0.25	0.27	0.29	0.31	0.33	0.35	0.37
40	0.28	0.29	0.31	0.33	0.35	0.37	0.39	0.41	0.43	0.45	0.48	0.51
50	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.53	0.57	0.61	0.65
60	0.45	0.48	0.51	0.53	0.55	0.57	0.60	0.63	0.66	0.69	0.73	0.78
70	–	–	–	–	–	0.66	0.69	0.71	0.75	0.81	0.87	0.92
80	–	–	–	–	–	–	0.76	0.81	0.87	0.93	1.00	1.06
90	–	–	–	–	–	–	–	0.92	0.99	1.06	1.13	1.20
100	–	–	–	–	–	–	–	–	1.10	1.18	1.26	1.34

TABLE 281. — Standard Calibration Curve for Pt. — Pt. Rh. (10% Rh.) Thermo-Element.

Giving the temperature for every 100 microvolts. For use in conjunction with a deviation curve determined by calibration of the particular element at some of the following fixed points:

Water	boiling-pt.	100.0	643mv.	Silver	melting-pt.	960.2	9111mv.
Napthalene	" "	217.95	1585	Gold	" "	1062.6	10296
Tin	melting-pt.	231.9	1706	Copper	" "	1082.8	10534
Benzophenone	boiling-pt.	305.9	2365	Li_2SiO_3	" "	1201.	11941
Cadmium	melting-pt.	320.9	2503	Diopside	" "	1391.5	14230
Zinc	" "	419.4	3430	Nickel	" "	1452.6	14973
Sulphur	boiling-pt.	444.55	3672				
Antimony	melting-pt.	630.0	5530	Palladium	" "	1549.5	16144
Aluminum	" "	658.7	5827	Platinum	" "	1755.	18608

E micro-volts.	0	1000.	2000.	3000.	4000.	5000.	6000.	7000.	8000.	9000.	E micro-volts.
	Temperatures, °C.										
0.	0.0	147.1	265.4	374.3	478.1	578.3	675.3	769.5	861.1	950.4	0.
100.	17.8	159.7	276.6	384.9	488.3	588.1	684.8	778.8	870.1	959.2	100.
200.	34.5	172.1	287.7	395.4	498.4	597.9	694.3	788.0	879.1	968.0	200.
300.	50.3	184.3	298.7	405.9	508.5	607.7	703.8	797.2	888.1	976.7	300.
400.	65.4	196.3	309.7	416.3	518.6	617.4	713.3	806.4	897.1	985.4	400.
500.	80.0	208.1	320.6	426.7	528.6	627.1	722.7	815.6	906.1	994.1	500.
600.	94.1	219.7	331.5	437.1	538.6	636.8	732.1	824.7	915.0	1002.8	600.
700.	107.8	231.2	342.3	447.4	548.6	646.5	741.5	833.8	923.9	1011.5	700.
800.	121.2	242.7	353.0	457.7	558.5	656.1	750.9	842.9	932.8	1020.1	800.
900.	134.3	254.1	363.7	467.9	568.4	665.7	760.2	852.0	941.6	1028.7	900.
1000.	147.1	265.4	374.3	478.1	578.3	675.3	769.5	861.1	950.4	1037.3	1000.

E micro-volts.	10000.	11000.	12000.	13000.	14000.	15000.	16000.	17000.	18000.	E micro-volts.
	Temperatures, °C.									
0.	1037.3	1122.2	1205.9	1289.3	1372.4	1454.8	1537.5	1620.9	1704.3	0.
100.	1045.9	1130.6	1214.2	1297.7	1380.7	1463.0	1545.8	1629.2	1712.6	100.
200.	1054.4	1139.0	1222.6	1306.0	1389.0	1471.2	1554.1	1637.6	1721.0	200.
300.	1062.9	1147.4	1230.9	1314.3	1397.3	1479.4	1562.4	1645.9	1729.3	300.
400.	1071.4	1155.8	1239.3	1322.6	1405.6	1487.7	1570.8	1654.3	1737.7	400.
500.	1079.9	1164.2	1247.6	1330.9	1413.8	1496.0	1579.1	1662.6	1746.0	500.
600.	1088.4	1172.5	1255.9	1339.2	1422.0	1504.3	1587.5	1670.9	1754.3	600.
700.	1096.9	1180.9	1264.3	1347.5	1430.2	1512.6	1595.8	1679.3		700.
800.	1105.4	1189.2	1272.6	1355.8	1438.4	1520.9	1604.2	1687.6		800.
900.	1113.8	1197.6	1281.0	1364.1	1446.6	1529.2	1612.5	1696.0		900.
1000.	1122.2	1205.9	1289.3	1372.4	1454.8	1537.5	1620.9	1704.3		1000.

TABLE 282. — Standard Calibration Curve for Copper — Constantan Thermo-Element.

For use in conjunction with a deviation curve determined by the calibration of the particular element at some of the following fixed points:
Water, boiling-point, 100°, 4276 microvolts; Napthalene, boiling-point, 217.95, 10248 mv.; Tin, melting-point, 231.9, 11009 mv.; Benzophenone, boiling-point, 305.9, 15203 mv.; Cadmium, melting-point, 320.9, 16083 mv.

E. micro-volts.	0	1000.	2000.	3000.	4000.	5000.	6000.	7000.	8000.	9000.	E micro-volts.
	Temperatures, °C.										
0.	0.00	25.27	49.20	72.08	94.07	115.31	135.91	155.95	175.50	194.62	0.
100.	2.60	27.72	51.53	74.31	96.23	117.40	137.94	157.92	177.43	196.51	100.
200.	5.17	30.15	53.85	76.54	98.38	119.48	139.96	159.89	179.36	198.40	200.
300.	7.73	32.57	56.16	78.76	100.52	121.56	141.98	161.86	181.28	200.28	300.
400.	10.28	34.98	58.46	80.97	102.66	123.63	143.99	163.82	183.20	202.16	400.
500.	12.81	37.38	60.76	83.17	104.79	125.69	146.00	165.78	185.11	204.04	500.
600.	15.33	39.77	63.04	85.37	106.91	127.75	148.00	167.73	187.02	205.91	600.
700.	17.83	42.15	65.31	87.56	109.02	129.80	150.00	169.68	188.93	207.78	700.
800.	20.32	44.51	67.58	89.74	111.12	131.84	151.99	171.62	190.83	209.64	800.
900.	22.80	46.86	69.83	91.91	113.22	133.88	153.97	173.56	192.73	211.50	900.
1000.	25.27	49.20	72.08	94.07	115.31	135.91	155.95	175.50	194.62	213.36	1000.

E micro-volts.	10000.	11000.	12000.	13000.	14000.	15000.	16000.	17000.	18000.	E micro-volts.
	Temperatures, °C.									
0.	213.36	231.74	249.82	267.60	285.13	302.42	319.49	336.36	353.09	0.
100.	215.21	233.56	251.61	269.36	286.87	304.14	321.19	338.04		100.
200.	217.06	235.38	253.40	271.12	288.61	305.85	322.88	339.72		200.
300.	218.91	237.20	255.18	272.88	290.35	307.56	324.57	341.40		300.
400.	220.75	239.01	256.96	274.64	292.08	309.27	326.26	343.07		400.
500.	222.59	240.82	258.74	276.40	293.81	310.98	327.95	344.74		500.
600.	224.43	242.63	260.52	278.15	295.54	312.69	329.64	346.41		600.
700.	226.26	244.43	262.29	279.90	297.26	314.39	331.32	348.08		700.
800.	228.09	246.23	264.06	281.65	298.98	316.09	333.00	349.75		800.
900.	229.92	248.03	265.83	283.39	300.70	317.79	334.68	351.42		900.
1000.	231.74	249.82	267.60	285.13	302.42	319.49	336.36	353.09		1000.

Cf. Day and Sosman, Am. Jour. Sci. 29, p. 93, 32, p. 51; ; *ibid.* R. B. Sosman, 30, p. 1.

RADIATION CONSTANTS.

TABLE 283.—Radiation Formulæ and Constants for Perfect Radiator.

The radiation per sq. cm. from a "black body" (exclusive of convection losses) at the temperature T° (absolute, C) to one at t° is equal to

$$J = \sigma\,(T^4 - t^4) \quad \text{(Stefan-Boltzmann)};$$

where $\sigma = 1.374 \times 10^{-12}$ gram-calories per second per sq. centimeter.
$= 8.26 \times 10^{-11}$ " " " minute " " "
$= 5.75 \times 10^{-12}$ watts per sq. centimeter.

The distribution of this energy in the spectrum is represented by Planck's formula:

$$J_\lambda = C_1 \lambda^{-5}\left[e^{\frac{C_2}{\lambda T}} - 1\right]^{-1}$$

where J_λ is the intensity of the energy at the wave-length λ (λ expressed in microns, μ) and e is the base of the Napierian logarithms.

$C_1 = 9.226 \times 10^{-23}$ for J in $\frac{gram.\ cal.}{sec.\ cm.^2} = 3.86 \times 10^{-22}$ for J in $\frac{watts}{cm.^2}$

$C_2 = 1.4450$ for λ in *cm.*

$J_{max} = 3.11 \times 10^{+4}\ T^5$ for J in $\frac{gram.\ cal.}{sec.\ cm.^2} = 1.30 \times 10^{+5}\ T^5$ for J in $\frac{watts}{cm.^2}$

$\lambda_{max} T = 0.2910$ for λ in *cm.*

h = Planck's unit = elementary "Wirkungs quantum" $= 6.83 \times 10^{-27}$ ergs. sec.

k = constant of entropy equation $= 1.42 \times 10^{-16}$ ergs./degrees.

TABLE 284.—Radiation in Gram-Calories per 24 Hours per sq. cm. from a Perfect Radiator at t° C to an absolutely Cold Space (—273° C).

Computed from the Stefan-Boltzmann formula.

t° C	J	t° C	J	t° C	J	t° C	J	t° C	J	t° C	J
—273	0	—120	65	—10	571	+12	787	+34	1059	+56	1400
—220	1	—110	84	—8	588	+14	808	+36	1087	+58	1430
—210	2	—100	107	—6	606	+16	831	+38	1115	+60	1470
—200	3	—90	134	—4	625	+18	855	+40	1145	+70	1650
—190	5	—80	165	—2	643	+20	879	+42	1174	+80	1850
—180	9	—70	201	0	662	+22	903	+44	1204	+90	2070
—170	13	—60	245	+2	682	+24	928	+46	1234	+100	2310
—160	19	—50	294	+4	701	+26	953	+48	1265	+200	5960
—150	27	—40	350	+6	722	+28	979	+50	1298	+1000	313×10^3
—140	38	—30	416	+8	744	+30	1005	+52	1330	+2000	318×10^4
—130	50	—20	488	+10	765	+32	1032	+54	1363	+5000	921×10^5

TABLE 285.—Values of J_λ for Various Temperatures Centigrade.

Ekholm, Met. Z. 1902, used $C_1 = 8346$ and $C_2 = 14349$, and for the unit of time the day.
For 10°, the values for J_λ have been multiplied by 10, for the other temperatures by 100.

λ	T = 100° C	30° C	15° C	0° C	—30° C	—80° C	λ	100° C	30° C	15° C	0° C	—30° C	—80° C
μ							μ						
2	1	0	0	0	0	0	18	511	2961	2557	2175	1491	623
3	80	41	18	7	1	0	19	443	2626	2281	1954	1363	594
4	469	508	272	138	27	1	20	386	2329	2034	1754	1242	561
5	1047	1777	1085	628	172	8	21	337	2068	1816	1574	1129	527
6	1526	3464	2296	1454	493	39	22	295	1840	1622	1413	1026	494
7	1768	4954	3481	2353	931	105	23	259	1639	1448	1270	931	460
8	1810	5928	4352	3088	1372	203	24	228	1462	1298	1141	846	428
9	1724	6382	4834	3646	1730	316	25	202	1307	1165	1028	768	398
10	1573	6386	4979	3781	1971	426	26	179	1170	1047	926	698	369
11	1398	6127	4833	3798	2098	520	28	142	947	850	757	579	317
12	1225	5712	4633	3676	2114	592	30	114	771	696	623	482	272
13	1063	5222	4300	3467	2090	640	40	44	311	285	259	209	130
14	918	4713	3930	3215	2004	666	50	20	146	135	124	102	67
15	792	4220	3556	2944	1889	673	60	10	77	72	66	55	38
16	683	3759	3198	2674	1760	663	80	4	27	25	24	20	14
17	590	3340	2862	2417	1626	649	100	2	12	11	10	9	7

COOLING BY RADIATION AND CONVECTION.

TABLE 286. — At Ordinary Pressures.

According to McFarlane* the rate of loss of heat by a sphere placed in the centre of a spherical enclosure which has a blackened surface, and is kept at a constant temperature of about 14° C, can be expressed by the equations

$$e = .000238 + 3.06 \times 10^{-6}t - 2.6 \times 10^{-8}t^2,$$

when the surface of the sphere is blackened, or

$$e = .000168 + 1.98 \times 10^{-6}t - 1.7 \times 10^{-8}t^2,$$

when the surface is that of polished copper. In these equations, e is the amount of heat lost in c. g. s. units, that is, the quantity of heat, small calories, radiated per second per square centimeter of surface of the sphere, per degree difference of temperature t, and t is the difference of temperature between the sphere and the enclosure. The medium through which the heat passed was moist air. The following table gives the results.

Difference of temperature t	Value of e. Polished surface.	Value of e. Blackened surface.	Ratio.
5	.000178	.000252	.707
10	.000186	.000266	.699
15	.000193	.000279	.692
20	.000201	.000289	.695
25	.000207	.000298	.694
30	.000212	.000306	.693
35	.000217	.000313	.693
40	.000220	.000319	.693
45	.000223	.000323	.690
50	.000225	.000326	.690
55	.000226	.000328	.690
60	.000226	.000328	.690

TABLE 287. — At Different Pressures.

Experiments made by J. P. Nicol in Tait's Laboratory show the effect of pressure of the enclosed air on the rate of loss of heat. In this case the air was dry and the enclosure kept at about 8° C.

Polished surface. t	Polished surface. et	Blackened surface. t	Blackened surface. et
Pressure 76 cms. of Mercury.			
63.8	.00987	61.2	.01746
57.1	.00862	50.2	.01360
50.5	.00736	41.6	.01078
44.8	.00628	34.4	.00860
40.5	.00562	27.3	.00640
34.2	.00438	20.5	.00455
29.6	.00378	–	–
23.3	.00278	–	–
18.6	.00210	–	–
Pressure 10.2 cms. of Mercury.			
67.8	.00492	62.5	.01298
61.1	.00433	57.5	.01158
55	.00383	53.2	.01048
49.7	.00340	47.5	.00898
44.9	.00302	43.0	.00791
40.8	.00268	28.5	.00490
Pressure 1 cm. of Mercury.			
65	.00388	62.5	.01182
60	.00355	57.5	.01074
50	.00286	54.2	.01003
40	.00219	41.7	.00726
30	.00157	37.5	.00639
23.5	.00124	34.0	.00569
–		27.5	.00446
–	–	24.2	.00391

* "Proc. Roy. Soc." 1872.
† "Proc. Roy. Soc." Edinb. 1869.
See also Compan, Annal. de chi. et phys. 26, p. 526.

COOLING BY RADIATION AND CONVECTION.

TABLE 288. — Cooling of Platinum Wire in Copper Envelope.

Bottomley gives for the radiation of a bright platinum wire to a copper envelope when the space between is at the highest vacuum attainable the following numbers: —

$t = 408°$ C., $et = 378.8 \times 10^{-4}$, temperature of enclosure 16° C.
$t = 505°$ C., $et = 726.1 \times 10^{-4}$, " " 17° C.

It was found at this degree of exhaustion that considerable relative change of the vacuum produced very small change of the radiating power. The curve of relation between degree of vacuum and radiation becomes asymptotic for high exhaustions. The following table illustrates the variation of radiation with pressure of air in enclosure.

Temp. of enclosure 16° C., $t = 408°$ C.		Temp. of enclosure 17° C., $t = 505°$ C.	
Pressure in mm.	*et*	Pressure in mm.	*et*
740.	8137.0×10^{-4}	0.094	1688.0×10^{-4}
440.	7971.0 "	.053	1255.0 "
140.	7875.0 "	.034	1126.0 "
42.	7591.0 "	.013	920.4 "
4.	6036.0 "	.0046	831.4 "
0.444	2683.0 "	.00052	767.4 "
.070	1045.0 "	.00019	746.4 "
.034	727.3 "	Lowest reached but not measured	726.1 "
.012	539.2 "		
.0051	436.4 "		
.00007	378.8 "		

TABLE 289. — Effect of Pressure on Loss of Heat at Different Temperatures.

The temperature of the enclosure was about 15° C. The numbers give the total radiation in therms per square centimeter per second.

Temp. of wire in C°.	Pressure in mm.				
	10.0	1.0	0.25	0.025	About 0.1 M.
100°	0.14	0.11	0.05	0.01	0.005
200	.31	.24	.11	.02	.0055
300	.50	.38	.18	.04	.0105
400	.75	.53	.25	.07	.025
500	–	.69	.33	.13	.055
600	–	.85	.45	.23	.13
700	–	–	–	.37	.24
800	–	–	–	.56	.40
900	–	–	–	–	.61

NOTE. — An interesting example (because of its practical importance in electric lighting) of the effect of difference of surface condition on the radiation of heat is given on the authority of Mr. Evans and himself in Bottomley's paper. The energy required to keep up a certain degree of incandescence in a lamp when the filament is dull black and when it is "flashed" with coating of hard bright carbon, was found to be as follows: —

Dull black filament, 57.9 watts.
Bright " " 39.8 watts.

Table 290.

PROPERTIES OF STEAM.

Metric Measure.

The temperature Centigrade and the absolute temperature in degrees Centigrade, together with other data for steam or water vapor stated in the headings of the columns, are here given. The quantities of heat are in therms or calories according as the gram or the kilogram is taken as the unit of mass.

Temp. C.	Absolute temp.	Pressure in mm. of mercury.	Pressure in grams per sq. centimeter $= p$.	Pressure in atmospheres.	Total heat of evaporation from 0° at $t° = H$.	Heat of liquid $= h$.	Heat of evaporation $= H - h$.	Outer latent or external-work heat $= Apv$.*	Total heat of steam $= H - Apv$.	Inner latent or internal-work heat $= H - (h + Apv)$.	Liters per gram, or cubic meters per kilog. $= v$.	Ratio of inner latent heat to volume of steam.†
0°	273	4.60	6.25	0.006	606.5	0.00	606.5	31.07	575.4	575.4	210.66	2.732
5	278	6.53	8.88	.009	608.0	5.00	603.0	31.47	576.5	571.5	150.23	3.805
10	283	9.17	12.47	.012	609.5	10.00	599.5	31.89	577.7	567.7	108.51	5.231
15	288	12.70	17.27	.017	611.1	15.00	596.0	32.32	578.8	563.7	79.35	7.104
20	293	17.39	23.64	.023	612.6	20.01	592.6	32.75	579.8	559.8	58.72	9.532
25	298	23.55	32.02	0.031	614.1	25.02	589.1	33.20	580.9	555.9	43.96	12.64
30	303	31.55	42.89	.042	615.6	30.03	585.6	33.66	582.0	552.0	33.27	16.59
35	308	41.83	56.87	.055	617.2	35.04	582.1	34.12	583.1	548.2	25.44	21.54
40	313	54.91	74.65	.072	618.7	40.05	578.6	34.59	584.1	544.1	19.64	27.70
45	318	71.39	97.06	.094	620.2	45.07	575.1	35.06	585.2	540.1	15.31	35.26
50	323	91.98	125.0	0.121	621.7	50.09	571.7	35.54	586.2	536.1	12.049	44.49
55	328	117.47	159.7	.155	623.3	55.11	568.2	36.02	587.2	532.1	9.561	55.65
60	333	148.79	202.3	.196	624.8	60.13	564.7	36.51	588.3	528.1	7.653	69.02
65	338	186.94	254.2	.246	626.3	65.17	561.1	37.00	589.3	524.2	6.171	84.94
70	343	233.08	316.9	.306	627.8	70.20	557.6	37.48	590.4	520.2	5.014	103.75
75	348	288.50	392.3	0.380	629.4	75.24	554.1	37.96	591.4	516.2	4.102	125.8
80	353	354.62	482.1	.466	630.9	80.28	550.6	38.42	592.5	512.2	3.379	151.6
85	358	433.00	588.7	.570	632.4	85.33	547.1	38.88	593.5	508.2	2.800	181.5
90	363	525.39	714.4	.691	633.9	90.38	543.6	39.33	594.6	504.2	2.334	216.0
95	368	633.69	861.7	.834	635.5	95.44	540.0	39.76	595.7	500.3	1.957	255.7
100	373	760.00	1033.	1.000	637.0	100.5	536.5	40.20	596.8	496.3	1.6496	300.8
105	378	906.41	1232.	.193	638.5	105.6	533.0	40.63	597.9	492.3	1.3978	352.2
110	383	1075.4	1462.	.415	640.0	110.6	529.4	41.05	599.0	488.4	1.1903	410.3
115	388	1269.4	1726.	.670	641.6	115.7	525.8	41.46	600.1	484.4	1.0184	475.6
120	393	1491.3	2027.	.962	643.1	120.8	522.3	41.86	601.2	480.4	0.8752	549.0
125	398	1743.9	2371.	2.295	644.6	125.9	518.7	42.25	602.4	476.5	0.7555	630.7
130	403	2030.3	2760.	2.671	646.1	131.0	515.1	42.63	603.5	472.5	0.6548	721.6
135	408	2353.7	3200.	3.097	647.7	136.1	511.6	43.01	604.7	468.6	0.5698	822.3
140	413	2717.6	3695.	3.576	649.2	141.2	508.0	43.38	605.8	464.6	0.4977	933.5
145	418	3125.6	4249.	4.113	650.7	146.3	504.4	43.73	607.0	460.7	0.4363	1055.7
150	423	3581.2	4869.	4.712	652.2	151.5	500.8	44.09	608.2	456.7	0.3839	1190.
155	428	4088.6	5589.	5.380	653.8	156.5	497.2	44.43	609.3	452.8	0.3388	1336.
160	433	4651.6	6324.	6.120	655.3	161.7	493.5	44.76	610.5	448.8	0.3001	1496.
165	438	5274.5	7171.	6.940	656.8	166.9	489.9	45.09	611.7	444.8	0.2665	1669.
170	443	5961.7	8105.	7.844	658.3	172.0	486.3	45.40	612.9	440.9	0.2375	1856.
175	448	6717.4	9133.	8.839	659.9	177.2	482.7	45.71	614.2	436.9	0.2122	2059.
180	453	7546.4	10260.	9.929	661.4	182.4	479.0	46.01	615.4	433.0	0.1901	2277.
185	458	8453.2	11490.	11.123	662.9	187.6	475.3	46.30	616.6	429.0	0.1708	2512.
190	463	9442.7	12838.	12.425	664.4	192.8	471.7	46.59	617.9	425.0	0.1538	2763.
195	468	10520.	14303.	13.842	666.0	198.0	468.0	46.86	619.1	421.1	0.1389	3031.
200	473	11689.	15892.	15.380	667.5	203.2	464.3	47.13	620.4	417.1	0.1257	3318.

* Where A is the reciprocal of the mechanical equivalent of the thermal unit.

† $= \frac{H-(h+Apv)}{v} = \frac{\text{internal-work pressure}}{\text{mechanical equivalent of heat}}$. Where v is taken in litres the pressure is given per square decimetre, and where v is taken in cubic metres the pressure is given per square metre,—the mechanical equivalent being that of the therm and the kilogram-degree or calorie respectively.

TABLE 291.

PROPERTIES OF STEAM.

British Measure.

The quantities given in the different columns of this table are sufficiently explained by the headings. The abbreviation B. T. U. stands for British thermal units. With the exception of column 3, which was calculated for this table, the data are taken from a table given by Dwelshauvers-Dery (Trans. Am. Soc. Mech. Eng. vol. xi.).

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
1	144	0.068	102.0	334.23	0.0030	70.1	980.6	62.34	1043.	1113.0
2	288	.136	126.3	173.23	.0058	94.4	961.4	64.62	1026.	1120.4
3	432	.204	141.6	117.98	.0085	109.9	949.2	66.58	1011.	1127.0
4	576	.272	153.1	89.80	.0111	121.4	940.2	67.06	1007.	1128.6
5	720	.340	162.3	72.50	.0137	130.7	932.8	67.89	1001.	1131.4
6	864	0.408	170.1	61.10	0.0163	138.6	926.7	68.58	995.2	1133.8
7	1008	.476	176.9	53.00	.0189	145.4	921.3	69.18	990.5	1135.9
8	1152	.544	182.9	46.60	.0214	151.5	916.5	69.71	986.2	1137.7
9	1296	.612	188.3	41.82	.0239	156.9	912.2	70.18	982.4	1139.4
10	1440	.680	193.2	37.80	.0264	161.9	908.3	70.61	979.0	1140.9
11	1584	0.748	197.8	34.61	0.0289	166.5	904.8	70.99	975.8	1142.3
12	1728	.816	202.0	31.90	.0314	170.7	901.5	71.34	972.8	1143.5
13	1872	.884	205.9	29.58	.0338	174.7	898.4	71.68	970.0	1144.7
14	2016	.952	209.5	27.59	.0362	178.4	895.4	72.00	967.4	1145.9
15	2160	1.020	213.0	25.87	.0387	181.9	892.7	72.29	965.0	1146.9
16	2304	1.088	216.3	24.33	0.0411	185.2	890.1	72.57	962.7	1147.9
17	2448	.156	219.4	22.98	.0435	188.4	887.6	72.82	960.4	1148.9
18	2592	.224	222.4	21.78	.0459	191.4	885.3	73.07	958.3	1149.8
19	2736	.292	225.2	20.70	.0483	194.3	883.1	73.30	956.3	1150.6
20	2880	.360	227.9	19.72	.0507	197.0	880.9	73.53	954.4	1151.4
21	3024	1.429	230.5	18.84	0.0531	199.7	878.8	73.74	952.6	1152.2
22	3168	.497	233.0	18.03	.0554	202.2	876.8	73.94	950.8	1153.0
23	3312	.565	235.4	17.30	.0578	204.7	874.9	74.13	949.1	1153.7
24	3456	.633	237.7	16.62	.0602	207.0	873.1	74.32	947.4	1154.4
25	3600	.701	240.0	15.99	.0625	209.3	871.3	74.51	945.8	1155.1
26	3744	1.769	242.2	15.42	0.0649	211.5	869.6	74.69	944.3	1155.8
27	3888	.837	244.3	14.88	.0672	213.7	867.9	74.85	942.8	1156.4
28	4032	.905	246.3	14.38	.0695	215.7	866.3	75.01	941.3	1157.1
29	4176	.973	248.3	13.91	.0619	217.8	864.7	75.17	939.9	1157.7
30	4320	2.041	250.2	13.48	.0742	219.7	863.2	75.33	938.5	1158.3
31	4464	2.109	252.1	13.07	0.0765	221.6	861.7	75.47	937.2	1158.8
32	4608	.177	253.9	12.68	.0788	223.5	860.3	75.61	935.9	1159.4
33	4752	.245	255.7	12.32	.0811	225.3	858.9	75.76	934.6	1159.9
34	4896	.313	257.5	11.98	.0835	227.1	857.5	75.89	933.4	1160.5
35	5040	.381	259.2	11.66	.0858	228.8	856.1	76.02	932.1	1161.0
36	5184	2.449	260.8	11.36	0.0881	230.5	854.8	76.16	931.0	1161.5
37	5328	.517	262.5	11.07	.0903	232.2	853.5	76.28	929.8	1162.0
38	5472	.585	264.0	10.79	.0926	233.8	852.3	76.40	928.7	1162.5
39	5616	.653	265.6	10.53	.0949	235.4	851.0	76.52	927.6	1162.9
40	5760	.722	267.1	10.29	.0972	236.9	849.8	76.63	926.5	1163.4
41	5904	2.789	268.6	10.05	0.0995	238.5	848.7	76.75	925.4	1163.9
42	6048	.857	270.1	9.83	.1018	239.9	847.5	76.86	924.4	1164.3
43	6192	.925	271.5	9.61	.1040	241.4	846.4	76.97	923.3	1164.7
44	6336	.993	272.9	9.41	.1063	242.9	845.2	77.07	922.3	1165.2
45	6480	3.061	274.3	9.21	.1086	244.3	844.1	77.18	921.3	1165.6
46	6624	3.129	275.6	9.02	0.1108	245.6	843.1	77.29	920.4	1166.0
47	6768	.197	277.0	8.84	.1131	247.0	842.0	77.39	919.4	1166.4
48	6912	.265	278.3	8.67	.1153	248.3	841.0	77.49	918.5	1166.8
49	7056	.333	279.6	8.50	.1176	249.7	840.0	77.58	917.5	1167.2

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
50	7200	3.401	280.8	8.34	0.1198	251.0	839.0	77.67	916.6	1167.6
51	7344	.469	282.1	8.19	.1221	252.2	838.0	77.76	915.7	1168.0
52	7488	.537	283.3	8.04	.1243	253.5	837.0	77.85	914.9	1168.3
53	7632	.605	284.5	7.90	.1266	254.7	836.0	77.94	914.0	1168.7
54	7776	.673	285.7	7.76	.1288	256.0	835.1	78.03	913.1	1169.1
55	7920	3.741	286.9	7.63	0.1310	257.1	834.2	78.12	912.3	1169.4
56	8064	.810	288.1	7.50	.1333	258.3	833.2	78.21	911.5	1169.8
57	8208	.878	289.2	7.38	.1355	259.5	832.3	78.29	910.6	1170.1
58	8352	.946	290.3	7.26	.1377	260.7	831.5	78.37	909.8	1170.5
59	8496	4.014	291.4	7.14	.1400	261.8	830.6	78.45	909.0	1170.8
60	8640	4.082	292.5	7.03	0.1422	262.9	829.7	78.53	908.2	1171.2
61	8784	.150	293.6	6.92	.1444	264.0	828.9	78.61	907.5	1171.5
62	8928	.218	294.7	6.82	.1466	265.1	828.0	78.68	906.7	1171.8
63	9072	.286	295.7	6.72	.1488	266.1	827.2	78.76	905.9	1172.1
64	9216	.354	296.7	6.62	.1511	267.2	826.4	78.83	905.2	1172.4
65	9360	4.422	297.8	6.52	0.1533	268.3	825.6	78.90	904.5	1172.8
66	9504	.490	298.8	6.43	.1555	269.3	824.8	78.97	903.7	1173.1
67	9648	.558	299.8	6.34	.1577	270.4	824.0	79.04	903.1	1173.4
68	9792	.626	300.8	6.25	.1599	271.4	823.2	79.11	902.3	1173.7
69	9936	.694	301.8	6.17	.1621	272.4	822.4	79.18	901.6	1174.0
70	10080	4.762	302.7	6.09	0.1643	273.4	821.6	79.25	900.9	1174.3
71	10224	.830	303.7	6.00	.1665	274.3	820.9	79.32	900.2	1174.6
72	10368	.898	304.6	5.93	.1687	275.3	820.1	79.39	899.5	1174.9
73	10512	.966	305.5	5.85	.1709	276.3	819.4	79.46	898.8	1175.1
74	10656	5.034	306.5	5.78	.1731	277.2	818.7	79.53	898.1	1175.4
75	10800	5.102	307.4	5.70	0.1753	278.2	817.9	79.59	897.5	1175.7
76	10944	.170	308.3	5.63	.1775	279.1	817.2	79.65	896.9	1176.0
77	11088	.238	309.2	5.57	.1797	280.0	816.5	79.71	896.2	1176.2
78	11232	.306	310.1	5.50	.1818	280.9	815.8	79.77	895.6	1176.5
79	11376	.374	310.9	5.43	.1840	281.8	815.1	79.83	895.0	1176.8
80	11520	5.442	311.8	5.37	0.1862	282.7	814.4	79.89	894.3	1177.0
81	11664	.510	312.7	5.31	.1884	283.6	813.8	79.95	893.7	1177.3
82	11808	.578	313.5	5.25	.1906	284.5	813.0	80.01	893.1	1177.6
83	11952	.646	314.4	5.19	.1928	285.3	812.4	80.07	892.5	1177.8
84	12096	.714	315.2	5.13	.1949	286.2	811.7	80.13	891.9	1178.0
85	12240	5.782	316.0	5.07	0.1971	287.0	811.1	80.19	891.3	1178.3
86	11384	.850	316.8	5.02	.1993	287.9	810.4	80.25	890.7	1178.6
87	12528	.918	317.6	4.96	.2015	288.7	809.8	80.30	890.1	1178.9
88	12672	.986	318.4	4.91	.2036	289.5	809.2	80.35	889.5	1179.0
89	12816	6.054	319.2	4.86	.2058	290.4	808.5	80.40	888.9	1179.3
90	12960	6.122	320.0	4.81	0.2080	291.2	807.9	80.45	888.4	1179.5
91	13104	.190	320.8	4.76	.2102	292.0	807.3	80.50	887.8	1179.8
92	13248	.258	321.6	4.71	.2123	292.8	806.7	80.56	887.2	1180.0
93	13392	.327	322.4	4.66	.2145	293.6	806.1	80.61	886.7	1180.3
94	13536	.396	323.1	4.62	.2166	294.3	805.5	80.66	886.1	1180.5
95	13680	6.463	323.9	4.57	0.2188	295.1	804.9	80.71	885.6	1180.7
96	13824	.531	324.6	4.53	.2209	295.9	804.3	80.76	885.0	1180.9
97	13968	.599	325.4	4.48	.2231	296.7	803.7	80.81	884.5	1181.2
98	14112	.667	326.1	4.44	.2252	297.4	803.1	80.86	884.0	1181.4
99	14256	.735	326.8	4.40	.2274	298.2	802.5	80.91	883.4	1181.6

TABLE 291 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
100	14400	6.803	327.6	4.356	0.2295	298.9	802.0	80.95	882.9	1181.8
101	14544	.871	328.3	.316	.2317	299.7	801.4	81.00	882.4	1182.1
102	14688	.939	329.0	.276	.2338	300.4	800.8	81.05	881.9	1182.3
103	14832	7.007	329.7	.237	.2360	301.1	800.3	81.10	881.4	1182.5
104	14976	.075	330.4	.199	.2381	301.9	799.7	81.14	880.8	1182.7
105	15120	7.143	331.1	4.161	0.2403	302.6	799.2	81.18	880.3	1182.9
106	15264	.211	331.8	.125	.2424	303.3	798.6	81.23	879.8	1183.1
107	15408	.279	332.5	.088	.2446	304.0	798.1	81.27	879.3	1183.4
108	15552	.347	333.2	.053	.2467	304.7	797.5	81.31	878.8	1183.6
109	15696	.415	333.8	.018	.2489	305.4	797.0	81.36	878.3	1183.8
110	15840	7.483	334.5	3.984	0.2510	306.1	796.5	81.41	877.9	1184.0
111	15984	.551	335.2	.950	.2531	306.8	795.9	81.45	877.4	1184.2
112	16128	.619	335.8	.917	.2553	307.5	795.4	81.50	876.9	1184.4
113	16272	.687	336.5	.885	.2574	308.2	794.9	81.54	876.4	1184.6
114	16416	.755	337.2	.853	.2596	308.8	794.4	81 58	875.9	1184.8
115	16560	7.823	337.8	3.821	0.2617	309.5	793.8	81.62	875.5	1185.0
116	16704	.891	338.5	.790	.2638	310.2	793.3	81.66	875.0	1185.2
117	16848	.959	339.1	.760	.2660	310.8	792.8	81.70	874.5	1185.4
118	16992	8.027	339.7	.730	.2681	311.5	792.3	81.74	874.1	1185.6
119	17136	.095	340.4	.700	.2702	312.1	791.8	81.78	873.6	1185.7
120	17280	8.163	341.0	3.671	0.2724	312.8	791.3	81.82	873.2	1185.9
121	17424	.231	341.6	.643	.2745	313.4	790.8	81.86	872.7	1186.1
122	17568	.299	342.2	.615	.2766	314.1	790.3	81.90	872.2	1186.3
123	17712	.367	342.8	.587	.2787	314.7	789.9	81.94	871.8	1186.5
124	17856	.435	343.5	.560	.2809	315.3	789.4	81.98	871.4	1186.7
125	18000	8.503	344.1	3.534	0.2830	316.0	788.9	82.02	870.9	1186.9
126	18144	.571	344.7	.507	.2851	316.6	788.4	82.06	870.5	1187.1
127	18288	.639	345.3	.481	.2872	317.2	787.9	82.09	870.0	1187.2
128	18432	.708	345.9	.456	.2893	317.8	787.5	82.13	869.6	1187.4
129	18576	.776	346.5	.431	.2915	318.4	787.0	82.17	869.2	1187.6
130	18720	8.844	347.1	3.406	0.2936	319.0	786.5	82.21	868.7	1187.8
131	18864	.912	347.6	.382	.2957	319.7	786.1	82.25	868.3	1188.0
132	19008	.980	348.2	.358	.2978	320.3	785.6	82.28	867.9	1188.1
133	19152	9.048	348.8	.334	.2999	320.9	785.1	82.32	867.5	1188.3
134	19296	.116	349.4	.310	.3021	321.5	784.7	82.35	867.0	1188.5
135	19440	9.184	349.9	3.287	0.3042	322.1	784.2	82.38	866.6	1188.7
136	19584	.252	350.5	.265	.3063	322.6	783.8	82.42	866.2	1188.8
137	19728	.320	351.1	.442	.3084	323.2	783.3	82.45	865.8	1189.0
138	19872	.388	351.6	.220	.3105	323.8	782.9	82.49	865.4	1189.2
139	20016	.456	352.2	.199	.3126	324.4	782.4	82.52	865.0	1189.4
140	20160	9.524	352.8	3.177	0.3147	325.0	782.0	82.56	864.6	1189.5
141	20304	.592	353.3	.156	.3168	325.5	781.6	82.59	864.2	1189.7
142	20448	.660	353.9	.135	.3190	326.1	781.1	82.63	863.8	1189.9
143	20592	.728	354.4	.115	.3211	326.7	780.7	82.66	863.4	1190.0
144	20736	.796	355.0	.094	.3232	327.2	780.3	82.69	863.0	1190.2
145	20880	9.864	355.5	3.074	0.3253	327.8	779.8	82.72	862.6	1190.4
146	21024	.932	356.0	.054	.3274	328.4	779.4	82.75	862.2	1190.5
147	21168	10.000	356.6	.035	.3295	328.9	779.0	82.79	861.8	1190.7
148	21312	.068	357.1	.016	.3316	329.5	778.6	82.82	861.4	1190.9
149	21456	.136	357.6	.997	.3337	330.0	778.1	82.86	861.0	1191.0

TABLE 291 (*continued*).

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pound of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
150	21600	10.204	358.2	2.978	0.3358	330.6	777.7	82.89	860.6	1191.2
151	21744	.272	358.7	.960	.3379	331.1	777.3	82.92	860.2	1191.3
152	21888	.340	359.2	.941	.3400	331.6	776.9	82.95	859.9	1191.5
153	22032	.408	359.7	.923	.3421	332.2	776.5	82.98	859.5	1191.7
154	22176	.476	360.2	.906	.3442	332.7	776.1	83.01	859.1	1191.8
155	22320	10.544	360.7	2.888	0.3462	333.2	775.7	83.04	858.7	1192.0
156	22464	.612	361.3	.871	.3483	333.8	775.3	83.07	858.3	1192.1
157	22608	.680	361.8	.854	.3504	334.3	774.9	83.10	858.0	1192.3
158	22752	.748	362.3	.837	.3525	334.8	774.5	83.13	857.6	1192.4
159	22896	.816	362.8	.820	.3546	335.3	774.1	83.16	857.2	1192.6
160	23040	10.884	363.3	2.803	0.3567	335.9	773.7	83.19	856.9	1192.7
161	23184	.952	363.8	.787	.3588	336.4	773.3	83.22	856.5	1192.9
162	23328	11.020	364.3	.771	.3609	336.9	772.9	83.25	856.1	1193.0
163	23472	.088	364.8	.755	.3630	337.4	772.5	83.28	855.8	1193.2
164	23616	.157	365.3	.739	.3650	337.9	772.1	83.31	855.4	1193.3
165	23760	11.225	365.7	2.724	0.3671	338.4	771.7	83.34	855.1	1193.5
166	23904	.293	366.2	.708	.3692	338.9	771.3	83.37	854.7	1193.6
167	24048	.361	366.7	.693	.3713	339.4	771.0	83.39	854.3	1193.8
168	24192	.429	367.2	.678	.3734	339.9	770.6	83.42	854.0	1193.9
169	24336	.497	367.7	.663	.3754	340.4	770.2	83.45	853.6	1194.1
170	24480	11.565	368.2	2.649	0.3775	340.9	769.8	83.48	853.3	1194.2
171	24624	.633	368.6	.634	.3796	341.4	769.4	83.51	852.9	1194.4
172	24768	.701	369.1	.620	.3817	341.9	769.1	83.54	852.6	1194.5
173	24912	.769	369.6	.606	.3838	342.4	768.7	83.56	852.2	1194.7
174	25056	.837	370.0	.592	.3858	342.9	768.3	83.59	851.9	1194.8
175	25200	11.905	370.5	2.578	0.3879	343.4	767.9	83.62	851.6	1194.9
176	25344	.973	371.0	.564	.3900	343.9	767.6	83.64	851.2	1195.1
177	25488	12.041	371.4	.550	.3921	344.3	767.2	83.67	850.9	1195.2
178	25632	.109	371.9	.537	.3942	344.8	766.8	83.70	850.5	1195.4
179	25776	.177	372.4	524	.3962	345.3	766.5	83.73	850.2	1195.5
180	25920	12.245	372.8	2.510	0.3983	345.8	766.1	83.75	849.9	1195.6
181	26064	.313	373.3	.497	.4004	346.3	765.8	83.77	849.5	1195.8
182	26208	.381	373.7	.485	.4025	346.7	765.4	83.80	849.2	1195.9
183	26352	.449	374.2	.472	.4046	347.2	765.0	83.83	848.9	1196.1
184	26496	.517	374.6	.459	.4066	347.7	764.7	83.86	848.5	1196.2
185	26640	12.585	375.1	2.447	0.4087	348.1	764.3	83.88	848.2	1196.3
186	26784	.653	375.5	.434	.4108	348.6	764.0	83.90	847.9	1196.5
187	26928	.721	376.0	.422	.4129	349.1	763.6	83.92	847.5	1196.6
188	27072	.789	376.4	.410	.4150	349.5	763.3	83.95	847.2	1196.7
189	27216	.857	376.8	.398	.4170	350.0	762.9	83.97	846.9	1196.9
190	27360	12.925	377.3	2.386	0.4191	350.4	762.6	83.99	846.6	1197.0
191	27504	.993	377.7	.374	.4212	350.9	762.2	84.02	846.3	1197.1
192	27648	13.061	378.2	.362	.4233	351.3	761.9	84.04	845.9	1197.3
193	27792	.129	378.6	.351	.4254	351.8	761.6	84.06	845.6	1197.4
194	27936	.197	379.0	.339	.4275	352.2	761.2	84.08	845.3	1197.5
195	28080	13.265	379.4	2.328	0.4296	352.7	760.9	84.10	845.0	1197.7
196	28224	.333	379.9	.317	.4316	353.1	760.5	84.13	844.7	1197.8
197	28368	.401	380.3	.306	.4337	353.6	760.2	84.16	844.4	1197.9
198	28512	.469	380.7	.295	.4358	354.0	759.9	84.19	844.0	1198.1
199	28656	.537	381.1	.284	.4379	354.4	759.5	84.21	843.7	1198.2

PROPERTIES OF STEAM.

British Measure.

Pressure in pounds per square inch.	Pressure in pounds per square foot.	Pressure in atmospheres.	Temp. in degrees Fahr.	Volume per pound in cubic feet.	Weight per cubic foot in pounds.	Heat of water per pound in B. T. U.	Internal latent heat per pouod of steam in B. T. U.	External latent heat per pound of steam in B. T. U.	Total latent heat per pound of steam in B. T. U.	Total heat per pound of steam in B. T. U.
200	28800	13.605	381.6	2.273	0.4399	354.9	759.2	84.23	843.4	1198.3
201	28944	13.673	382.0	.262	.4420	355.3	758.9	84.26	843.1	1198.4
202	29088	13.742	382.4	.252	.4441	355.8	758.5	84.28	842.8	1198.6
203	29232	13.810	382.8	.241	.4461	356.2	758.2	84.30	842.5	1198.7
204	29376	13.878	383.2	.231	.4482	356.6	757.9	84.33	842.2	1198.8
205	29520	13.946	383.7	2.221	0.4503	357.1	757.5	84.35	841.9	1199.0
206	29664	14.014	384.1	.211	.4523	357.5	757.2	84.37	841.6	1199.1
207	29808	14.082	384.5	.201	.4544	357.9	756.9	84.40	841.3	1199.2
208	29952	14.150	384.9	.191	.4564	358.3	756.6	84.42	841.0	1199.3
209	30096	14.218	385.3	.181	.4585	358.8	756.2	84.44	840.7	1199.4
210	30240	14.386	385.7	2.171	0.4605	359.2	755.9	84.46	840.4	1199.6
211	30384	14.454	386.1	.162	.4626	359.6	755.6	84.48	840.1	1199.7
212	30528	14.522	386.5	.152	.4646	360.0	755.3	84.51	839.8	1199.8
213	30672	14.590	386.9	.143	.4666	360.4	755.0	84.53	839.5	1199.9
214	30816	14.658	387.3	.134	.4687	360.9	754.7	84.55	839.2	1200.1
215	30960	14.726	387.7	2.124	0.4707	361.3	754.3	84.57	838.9	1200.2
216	31104	14.794	388.1	.115	.4727	361.7	754.0	84.60	838.6	1200.3
217	31248	14.862	388.5	.106	.4748	362.1	753.7	84.62	838.3	1200.4
218	31392	14.930	388.9	.097	.4768	362.5	753.4	84.64	838.0	1200.5
219	31536	14.998	389.3	.088	.4788	362.9	753.1	84.66	837.7	1200.7

RATIO OF THE ELECTROSTATIC TO THE ELECTROMAGNETIC UNIT OF ELECTRICITY = *V*.

Date.	*V* Cm. per sec.	Mean.	Determined by	Reference.
1856		3.11×10^{10}	R. Kohlrausch and W. Weber.	Pogg. Ann. 99; 1856.
1868	$2.75–2.92 \times 10^{10}$	2.84	Maxwell.	Phil. Trans.; 1868.
1869	2.71–2.88	2.81	Thomson and King.	B. A. Report; 1869.
1874	2.86–3.00	2.90	McKichan.	Phil. Mag. 47; 1874.
1879	2.950–3.018	2.981	Rowland.	Phil. Mag. 28; 1889.
1879	–	2.96	Ayrton and Perry.	Phil. Mag. 7; 1879.
1879	–	2.967	Hockin.	B. A. Report; 1879.
1880	–	2.955	Shida.	Phil. Mag. 10; 1880.
1881	2.98–3.00	2.99	Stoletow.	Jour. de Phys.; 1881.
1882	–	2.87	Exner.	Wien. Ber.; 1882.
1883	–	2.963	J. J. Thomson.	Phil. Trans.; 1883.
1884	3.001–3.029	3.019	Klemenčič.	Wien. Ber. 83, 89, 93; 1881–6.
"	3.016–3.031			
1886	·	3.015	Colley.	Wied. Ann. 28; 1886.
1886–8	2.999–3.009			
"	3.003–3.008	3.009	Himstedt.	Wied. Ann. 29, 33, 35; 1887–8.
"	3.005–3.015			
1888	–	2.92	Thomson, Ayrton and Perry.	Electr. Rev. 23; 1888–9.
1889	2.995–3.010	3.000	Rosa.	Phil. Mag. 28; 1889.
1890	–	2.996	J. J. Thomson and Searle.	Phil. Trans.; 1890.
1891	–	3.009	Pellat.	Jour. de Phys. 10; 1891.
1892	2.990–2.995	2.991	Abraham.	Ann. Chim. et Phys. 27; 1829.
1896	–	3.001	Hurmuzescu.	Ann. Chim. et Phys. 10; 1897.
1898	–	2.9973	Perot and Fabry.	Ann. Chim. et Phys. 13; 1898.
1898	–	3.026	Webster.	Phys. Rev. 6; 1898.
1899	–	3.009	Lodge and Glazebrook.	Cam. Phil. Soc. 18; 1899.
1904–7	2.99706–2.99741	2.9971	Rosa and Dorsey.	Bull. Bur. Standards 3; 1907.

The last of the above determinations is the result of an extended series of measurements upon various forms of condensers, and is believed to be correct within 1/100 per cent. This, however, assumes that the International Ohm is 10^9 c.g.s. units. The value of *V* is therefore subject to one-half the error of the International Ohm.

Table 293.

ABSOLUTE MEASUREMENTS OF CURRENTS AND OF THE ELECTROMOTIVE FORCE OF STANDARD CELLS.

Date.	Observer.	Method.	Electromotive Force* of		Electrochemical Equivalent of Silver.			References.
			Clark Cell at 15° C.	Weston Cell at 20° C.	Filter Paper Voltameter.	Porous Cup Voltameter.	No-Septum Voltameter.	
			Volts.	Volts.	Mg.	Mg.	Mg.	
1872	Clark	{ Electrodynamometer	1.4573	–			–	1
		{ Sine Galvanometer	1.4562		.		–	
1873	F. Kohlrausch	Tangent Galvanometer	–		1.1363		–	2
1882	Mascart	Current Balance			–		1.1156	3
1884	F. and W. Kohlrausch	Tangent Galvanometer			–		1.1183	4
1884	Rayleigh and Sedgwick	Current Balance	1.435		1.11794		–	5
1886	Gray	Sine Galvanometer	–		–		1.1183	6
1887	Koepsel	Electromag. Balance			1.11740	–	–	7
1890	Potier and Pellat	Electrodynamometer	–	–	–	–	1.1192	8
1896	Kahle †	Electrodynamometer	1.4325	1.0183	–		1.1183	9
1898	Patterson and Guthe	Electrodynamometer	–	–	1.1192		–	10
1899	Carhart and Guthe	Electrodynamometer	1.4333		–		–	11
1902	Callendar and King	Electrodynamometer	1.4334		–		–	12
1903	Pellat and Leduc	Electrodynamometer	–		1.1195			13
1904	Van Dijk and Kunst	Tangent Galvanometer	–	–	1.11823	–	–	14
1905	Guthe	Electrodynamometer	1.43296	1.01853	–	1.11773		15
1906	Van Dijk	Revision of 1904 work	–	–		1.1180		16
1907	Ayrton, Mather and Smith	Current Balance	1.4323	1.01819	–	–		17
1907	Smith, Mather and Lowry	With the above	–	–	1.11827	–		18
1908	Janet, Laporte and Jouaust ‡	Current Balance	–	1.01836	–	–		19
1908	Janet, Laporte and de la Gorce	With the above	–	–	1.11821	–		20
1908	Guillet ‡	Current Balance		1.01812	–	–		21
1908	Pellat ‡	Electrodynamometer	–	1.01831		–		22
1910	Haga and Boerema	Tangent Galvanometer	–	1.01825		–		23
1911	Rosa, Dorsey and Miller	Current Balance	–	1.01822		–	.	24
1911	Rosa, Vinal and McDaniel	With the above		–		1.11804	1.11804	25
1913	Haga and Boerema	Tangent Galvanometer			–	–	1.11802	26

1 Proc. Roy. Soc. May 30th, 1872 (Values in B. A. volts at 15.5 C.).
2 Pogg. Ann. vol. 149, p. 170 (anode wrapped in cloth).
3 J. de Phys. vol. 1, p. 109, vol. 3, p. 283.
4 Wied. Ann. vol. 27, p. 1, 1886.
5 Phil. Trans. A, vol. 175, p. 411, 1884.
6 Phil. Mag. vol. 22, p. 389, 1886.
7 Ann. d. Phys. vol. 31, p. 250, 1887.
8 J. de Phys. vol. 9, p. 381, 1890.
9 Zs f Instr. vol. 17, p. 97, 143–4, vol. 18, p. 276.
10 Phys. Rev. vol. 7, p. 257. (Added Ag_{20}).
11 Phys. Rev. vol. 9, p. 288, 1899.
12 Phil. Trans. A, vol. 199, p. 81, 1902.
13 C. R. vol. 136, p. 1649. (Muslin and filter paper both used.)
14 Ann. d. Phys. vol. 14, p. 569, 1904.
15 Bull. B. S. vol. 2, p. 33, 1906.
16 Ann. d. Phys. vol. 19, p. 249, 1906.
17 Phil. Trans. A, vol, 207, p. 463, 1908.
18 Phil. Trans. A, vol. 207, p. 545, 1908.
19 Bull. Int. Soc. Electr. vol. 8, p. 459, 1908. C. R. vol. 153, p. 718, 1911.
20 Bull. Int. Soc. Electr. vol. 8, p. 523, 1908.
21 Bull. Int. Soc. Electr. vol. 8, p. 535, 1908.
22 Bull. Int. Soc. Electr. vol. 8, p. 573, 1908.
23 Proc. Ak. Wiss. Amster. vol. 13, p. 587.
24 Bull. Bureau Standards, vol. 8, p. 269, 1912.
25 Bull. Bulletin Standards, vol. 8, p. 367, 1912.
26 Arch. Neer. Sci. IIIA, vol. 3, p. 324, 1913.

* The values given in these columns are not strictly absolute volts since they were in most cases determined in terms of an absolute ampere and an international ohm. Hence they may be called "semi-absolute." No absolute determinations of the ohm have been made in recent times, but some are in progress.

† Other values usually given as Kahle's results and officially used by the Reichsanstalt are voltameter determinations. To include them here would necessitate including many others similarly made. The value 1.1183 includes 5 filter paper determinations out of 26 observations.

‡ These values have been corrected for the difference between the French ohm at this time and that in use elsewhere. (C. R. vol. 153, p. 718.)

Measurements prior to Van Dijk (1906) and the subsequent filter paper voltameter determinations are now only of historical interest, but the large amount of work done in recent years makes these early determinations of especial interest. The errors due to the use of filter paper and other impurities (acid, alkali, colloidal matter, etc.) in the voltameter electrolyte make it impossible to apply corrections. The values for the cell are not readily comparable owing to variations in the voltage of the cell itself and the unit of resistance. See Dorn, Wiss. Abhl. der Phys. Tech. Reich., vol. II, p. 257. Since 1911 the voltage adopted for the Weston Normal Cell at 20° C. is 1.0183 international volts in all the leading countries. The international volt is to be distinguished from the absolute volt since it is based on the definition of the mercury ohm and the silver voltameter, taking the electrochemical equivalent of silver to be 1.11800 mg per coulomb. The difference between the international volt and the absolute volt is negligible for practical purposes. The temperature coefficient of the Weston Normal Cell (saturated type) is given in Table 294. The new value of the Weston cell was adopted in the United States on January 1, 1911.

Table 294.

COMPOSITION AND ELECTROMOTIVE FORCE OF VOLTAIC CELLS.

The electromotive forces given in this table approximately represent what may be expected from a cell in good working order, but with the exception of the standard cells all of them are subject to considerable variation.

(a) Double Fluid Cells.

Name of cell.	Negative pole.	Solution.	Positive pole.	Solution.	E.M.F. in volts.
Bunsen . .	Amalgamated zinc	1 part H_2SO_4 to 12 parts H_2O .	Carbon	Fuming H_2NO_3 .	1.94
" . .	" "	"	"	HNO_3, density 1.38	1.86
Chromate .	" "	12 parts $K_2Cr_2O_7$ to 25 parts of H_2SO_4 and 100 parts H_2O .	"	1 part H_2SO_4 to 12 parts H_2O .	2.00
" .	" "	1 part H_2SO_4 to 12 parts H_2O .	"	12 parts $K_2Cr_2O_7$ to 100 parts H_2O	2.03
Daniell* .	" "	1 part H_2SO_4 to 4 parts H_2O .	Copper	Saturated solution of $CuSO_4+5H_2O$	1.06
" .	" "	1 part H_2SO_4 to 12 parts H_2O .	"	"	1.09
" .	" "	5% solution of $ZnSO_4+6H_2O$	"	"	1.08
" .	" "	1 part NaCl to 4 parts H_2O .	"	"	1.05
Grove . .	" "	1 part H_2SO_4 to 12 parts H_2O .	Platinum	Fuming HNO_3 . .	1.93
" . .	" "	Solution of $ZnSO_4$	"	HNO_3, density 1.33	1.66
" . .	" "	H_2SO_4 solution, density 1.136 .	"	Concentrated HNO_3	1.93
" . .	" "	H_2SO_4 solution, density 1.136 .	"	HNO_3, density 1.33	1.79
" . .	" "	H_2SO_4 solution, density 1.06 .	"	"	1.71
" . .	" "	H_2SO_4 solution, density 1.14 .	"	HNO_3, density 1.19	1.66
" . .	" "	H_2SO_4 solution, density 1.06 .	"	" " "	1.61
" . .	" "	NaCl solution . .	"	" density 1.33	1.88
Marié Davy	" "	1 part H_2SO_4 to 12 parts H_2O	Carbon	Paste of protosulphate of mercury and water . . .	1.50
Partz . .	" "	Solution of $MgSO_4$	"	Solution of $K_2Cr_2O_7$	2.06

* The Minotto or Sawdust, the Meidinger, the Callaud, and the Lockwood cells are modifications of the Daniell, and hence have about the same electromotive force.

COMPOSITION AND ELECTROMOTIVE FORCE OF VOLTAIC CELLS.

Name of cell.	Negative pole.	Solution.	Positive pole.	E. M. F. in volts.
(b) Single Fluid Cells.				
Leclanche . . .	Amal. zinc	Solution of sal-ammoniac	Carbon. Depolarizer: manganese peroxide with powdered carbon	1.46
Chaperon . . .	" "	Solution of caustic potash	Copper. Depolarizer: CuO . . .	0.98
Edison-Lelande .	" "	"	"	0.70
Chloride of silver	Zinc . .	23 % solution of sal-ammoniac	Silver. Depolarizer: silver chl'ride	1.02
Law	" . .	15 % " "	Carbon	1.37
Dry cell (Gassner)	" . .	1 pt. ZnO, 1 pt. NH_4Cl, 3 pts. plaster of paris, 2 pts. $ZnCl_2$, and water to make a paste . .	"	1.3
Poggendorff . .	Amal. zinc	Solution of chromate of potash	"	1.08
" . . .	" "	12 parts $K_2Cr_2O_7$ + 25 parts H_2SO_4 + 100 parts H_2O . .	"	2.01
J. Regnault. . .	" "	1 part H_2SO_4 + 12 parts H_2O + 1 part $CaSO_4$ . .	Cadmium . . .	0.34
Volta couple . .	Zinc . .	H_2O	Copper	0.98
(c) Standard Cells.				
Weston normal .	Cadmi'm am'lgam	Saturated solution of $CdSO_4$	Mercury. Depolarizer: paste of Hg_2SO_4 and $CdSO_4$	1.0183* at 20° C
Clark standard .	Zinc am'lgam	Saturated solution of $ZnSO_4$	Mercury. Depolarizer: paste of Hg_2SO_4 and $ZnSO_4$	1.434‡ at 15° C
(d) Secondary Cells.				
Lead accumulator	Lead . .	H_2SO_4 solution of density 1.1 . . .	PbO_2	2.2†
Regnier (1) . . .	Copper .	$CuSO_4 + H_2SO_4$ . .	"	1.68 to 0.85, average 1.3.
" (2) . . .	Amal. zinc	$ZnSO_4$ solution . . .	" in H_2SO_4 .	2.36
Main	Amal. zinc	H_2SO_4 density ab't 1.1	"	2.50
Edison	Iron . .	KOH 20 % solution .	A nickel oxide .	1.1, mean of full discharge.

* E. M. F. hitherto used at Bureau of Standards. See p. 251. The temperature formula is $E_t = E_{20} - 0.0000406 (t-20) - 0.00000095 (t-20)^2 + 0.00000001 (t-20)^3$. ‡The value given is that adopted by the Chicago International Electrical Congress in 1893. The temperature formula is $E_t = E_{15} - 0.00119 (t-15) - 0.000007 (t-15)^2$.

† F. Streintz gives the following value of the temperature variation $\frac{dE}{dt}$ at different stages of charge:

E. M. F.	1.9223	1.9828	2.0031	2.0084	2.0105	2.0779	2.2070
$dE/dt \times 10^5$	140	228	335	285	255	130	73

Dolezalek gives the following relation between E. M. F. and acid concentration:

Per cent H_2SO_4	64.5	52.2	35.3	21.4	5.2
E.M.F., 0° C	2.37	2.25	2.10	2.00	1.89

CONTACT DIFFERENCE OF

Solids with Liquids and

Temperature of substances

	Carbon.	Copper.	Iron.	Lead.	Platinum.	Tin.	Zinc.
Distilled water	.01 to .17	.269 to .100	.148	.171	.285 to .345	.177	—.105 to +.156
Alum solution: saturated at 16°.5 C.	-	—.127	—.653	—.139	.246	—.225	—.536
Copper sulphate solution: sp. gr. 1.087 at 16°.6 C.	-	.103	-	-	-	-	-
Copper sulphate solution: saturated at 15° C.	-	.070	-	-	-	-	-
Sea salt solution: sp. gr. 1.18 at 20°.5 C.	-	—.475	—.605	-	—.856	—.334	—.565
Sal-ammoniac solution: saturated at 15°.5 C.	-	—.396	—.652	—.189	.059	—.364	—.637
Zinc sulphate solution: sp. gr. 1.125 at 16°.9 C.	-	-	-	-	-	-	—.238
Zinc sulphate solution: saturated at 15°.3 C.	-	-	-	-	-	-	—.430
One part distilled water + 3 parts saturated zinc sulphate solution	-	-	-	-	-	-	—.444
Strong sulphuric acid in distilled water:							
1 to 20 by weight	-	-	-	-	-	-	—.344
1 to 10 by volume	about —.035	-	-	-	-	-	-
1 to 5 by weight	-	-	-	-	-	-	-
5 to 1 by weight	.01 to 3.0	-	-	—.120	-	—.25	-
Concentrated sulphuric acid	.55 to .85	1.113	-	.72 to 1.252	1.3 to 1.6	-	-
Concentrated nitric acid	-	-	-	-	.672	-	-
Mercurous sulphate paste	-	-		-	-	-	-
Distilled water containing trace of sulphuric acid	-	-	-	-	-	-	—.241

* Everett's "Units and Physical Constants:" Table of

POTENTIAL IN VOLTS.

Liquids with Liquids in Air.*

during experiment about 16° C.

	Amalgamated zinc.	Brass.	Mercury.	Distilled water.	Alum solution: saturated at 16°.5 C.	Copper sulphate solution: saturated at 15° C.	Zinc sulphate solution: sp. gr. 1.25 at 16°.9 C.	Zinc sulphate solution: saturated at 15°.3 C.	One part distilled water + 3 pts. zinc sulphate.	Strong nitric acid.
Distilled water	.100	.231	–	–	–	—.043	–	.164	–	–
Alum solution: saturated at 16°.5 C.	–	—.014	–	–	–	–	–	–	–	–
Copper sulphate solution: sp. gr. 1.087 at 16°.6 C.	–		–	–	–	–	.090	–	–	–
Copper sulphate solution: saturated at 15° C. . .	–	–	–	—.043	–	–	–	.095	.102	–
Sea salt solution: sp. gr. 1.18 at 20°.5 C. . . .	–	—.435		–	–	–	–	–	–	–
Sal-ammoniac solution: saturated at 15°.5 C. .	–	—.348	–	–	–	–	–	–	–	–
Zinc sulphate solution: sp. gr. 1.125 at 16°.9 C.	–	–	–	–	–	–	–	–	–	–
Zinc sulphate solution: saturated at 15°.3 C. .	—.284	–	–	—.200	–	—.095	–	–		–
One part distilled water + 3 parts saturated zinc sulphate solution . .	–	–	–	–	–	—.102	–	–	–	–
Strong sulphuric acid in distilled water:										
1 to 20 by weight . . .	–	–	–	–	–	–	–	–	–	–
1 to 10 by volume . . .	—.358	–	–	–	–	–	–	–	–	–
1 to 5 by weight	.429	–	–	–	–	–	–	–	–	–
5 to 1 by weight	–	—.016	–	–	–	–	–	–	–	–
Concentrated sulphuric acid	.848	–	–	1.298	1.456	1.269	–	1.699	–	–
Concentrated nitric acid .			–	–	–	–	–	–	–	–
Mercurous sulphate paste .	–	–	.475	–	–	–	–	–	–	–
Distilled water containing trace of sulphuric acid.	–	–	–	–	–	–	–	–	–	.078

Ayrton and Perry's results, prepared by Ayrton.

TABLE 296.

CONTACT DIFFERENCE OF POTENTIAL IN VOLTS.

Solids with Solids in Air.*

The following results are the "Volta differences of potential," as measured by an electrometer. They represent the difference of the potentials of the air near each of two metals placed in contact. This should not be confused with the junction electromotive force at the junction of two metals in metallic contact, which has a definite value, proportional to the coefficient of Peltier effect. The Volta difference of potential has been found to vary with the condition of the metallic surfaces and with the nature of the surrounding gas. No great reliance, therefore, can be placed on the tabulated values.

The temperature of the substances during the experiment was about 18° C.

	Carbon.	Copper.	Iron.	Lead.	Platinum.	Tin.	Zinc.	Zinc amalgam.	Brass.
Carbon . . .	0	.370	.485	.858	.113	.795	1.096†	1.208†	.414†
Copper . . .	—.370	0	.146	.542	—.238	.456	.750	.894	.087
Iron	—.485†	—.146	0	.401†	—.369	.313†	.600†	.744†	—.064
Lead . . .	—.858	—.542	—.401	0	—.771	—.099	.210	.357†	—.472
Platinum . .	—.113†	.238	.369	.771	0	.690	.981	1.125†	.287
Tin	—.795†	—.458	—.313	.099	—.690	0	.281	.463	—.372
Zinc . . .	—1.096†	—.750	—.600	—.216	—.981	.281	0	.144	—.679
" amalgam	—1.208†	—.894	—.744	—.357†	—1.125†	—.463	—.144	0	—.822
Brass . . .	—.414	—.087	.064	.472	—.287	.372	.679	.822	0

The numbers not marked were obtained by direct experiment, those marked with a dagger by calculation, on the assumption that in a compound circuit of metals, all at the same temperature, there is no electromotive force.

The numbers in the same vertical column are the differences of potential in volts between the substance named at the top of the column and the substance named on the same line in the first column, when the two substances are in contact.

The metals used were those ordinarily obtained in commerce.

* Everett's "Units and Physical Constants." The table is from Ayrton and Perry's experiments, and was prepared by Ayrton.

DIFFERENCE OF POTENTIAL BETWEEN METALS IN SOLUTIONS OF SALTS.

The following numbers are given by G. Magnanini * for the difference of potential in hundredths of a volt between zinc in a normal solution of sulphuric acid and the metals named at the head of the different columns when placed in the solution named in the first column. The solutions were contained in a U-tube, and the sign of the difference of potential is such that the current will flow from the more positive to the less positive through the external circuit.

Strength of the solution in gram molecules per liter.		Zinc.†	Cadmium.†	Lead.	Tin.	Copper.	Silver.
No. of molecules.	Salt.	Difference of potential in centivolts.					
0.5	H_2SO_4	0.0	36.6	51.3	51.3	100.7	121.3
1.0	$NaOH$	—32.1	19.5	31.8	0.2	80.2	95.8
1.0	KOH	—42.5	15.5	32.0	—1.2	77.0	104.0
0.5	Na_2SO_4	1.4	35.6	50.8	51.4	101.3	120.9
1.0	$Na_2S_2O_3$	—5.9	24.1	45.3	45.7	38.8	64.8
1.0	KNO_3	11.8‡	31.9	42.6	31.1	81.2	105.7
1.0	$NaNO_3$	11.5	32.3	51.0	40.9	95.7	114.8
0.5	K_2CrO_4	23.9‡	42.8	41.2	40.9	94.6	121.0
0.5	$K_2Cr_2O_7$	72.8	61.1	78.4	68.1	123.6	132.4
0.5	K_2SO_4	1.8	34.7	51.0	40.9	95.7	114.8
0.5	$(NH_4)_2SO_4$	—0.5	37.1	53.2	57.6‡	101.5	125.7
0.25	$K_4FeC_6N_6$	—6.1	33.6	50.7	41.2	—‡	87.8
0.167	$K_6Fe_2(CN)_2$	41.0§	80.8	81.2	130.9	110.7	124.9
1.0	$KCNS$	—1.2	32.5	52.8	52.7	52.5	72.5
1.0	$NaNO_3$	4.5	35.2	50.2	49.0	103.6	104.6?
0.5	$SrNO_3$	14.8	38.3	50.6	48.7	103.0	119.3
0.125	$Ba(NO_3)_2$	21.9	39.3	51.7	52.8	109.6	121.5
1.0	KNO_3	—‡	35.6	47.5	49.9	104.8	115.0
0.2	$KClO_3$	15–10‡	39.9	53.8	57.7	105.3	120.9
0.167	$KBrO_3$	13–20‡	40.7	51.3	50.9	111.3	120.8
1.0	NH_4Cl	2.9	32.4	51.3	50.9	81.2	101.7
1.0	KF	2.8	22.5	41.1	50.8	61.3	61.5
1.0	$NaCl$	—	31.9	51.2	50.3	80.9	101.3
1.0	KBr	2.3	31.7	47.2	52.5	73.6	82.4
1.0	KCl	—	32.1	51.6	52.6	81.6	107.6
0.5	Na_2SO_3	—8.2	28.7	41.0	31.0	68.7	103.7
—‖	$NaOBr$	18.4	41.6	73.1	70.6‡	89.9	99.7
1.0	$C_4H_6O_6$	5.5	39.7	61.3	54.4§	104.6	123.4
0.5	$C_4H_6O_6$	4.1	41.3	61.6	57.6	110.9	125.7
0.5	$C_4H_4KNaO_6$	—7.9	31.5	51.5	42–47	100.8	119.7

* "Rend. della R. Acc. di Roma," 1890.
† Amalgamated.
‡ Not constant.
§ After some time.
‖ A quantity of bromine was used corresponding to NaOH = 1.

THERMOELECTRIC POWER.

The thermoelectric power of a circuit of two metals is the electromotive force produced by one degree C. difference of temperature between the junctions. The thermoelectric power varies with the temperature, thus: thermoelectric power $= Q = dE/dt = A + Bt$, where A is the thermoelectric power at 0° C., B is a constant, and t is the mean temperature of the junctions. The neutral point is the temperature at which $dE/dt = 0$, and its value is $-A/B$. When a current is caused to flow in a circuit of two metals originally at a uniform temperature, heat is liberated at one of the junctions and absorbed at the other. The rate of production or liberation of heat at each junction, or Peltier effect, is given in calories per second, by multiplying the current by the coefficient of the Peltier effect. This coefficient in calories per coulomb $= QT/J$, in which Q is in volts, T is the absolute temperature of the junction, and $J = 4.19$. Heat is also liberated or absorbed in each of the metals as the current flows through portions of varying temperature. The rate of production or liberation of heat in each metal, or the Thomson effect, is given in calories per second by multiplying the current by the coefficient of the Thomson effect. This coefficient, in calories per coulomb, $= BT\theta/J$, in which B is in volts per degree C., T is the mean absolute temperature of the junctions, and θ is the difference of temperature of the junctions. (BT) is Sir W. Thomson's "Specific Heat of electricity." The algebraic signs are so chosen in the following table that when A is positive, the current flows in the metal considered from the cold junction to the hot. When B is positive, Q increases (algebraically) with the temperature. The values of A, B, and thermoelectric power, in the following table are with respect to lead as the other metal of the thermoelectric circuit. The thermoelectric power of a couple composed of two metals, 1 and 2, is given by subtracting the value for 2 from that for 1; when this difference is positive, the current flows from the cold junction to the hot in 1. In the following table, A is given in microvolts, B in microvolts per degree C., and the neutral point in degrees C.

The table has been compiled from the results of Becquerel, Matthiessen and Tait; in reducing the results, the electromotive force of the Grove and Daniell cells has been taken as 1.95 and 1.07 volts. The value for constantin was reduced from results given in Landolt-Börnstein's tables. The thermoelectric powers of antimony and bismuth alloys are given by Becquerel in the reference given below.

Substance.	A Microvolts.	B Microvolts.	Thermoelectric power at mean temp. of junctions (microvolts).		Neutral point $-\frac{A}{B}$.	Authority.
			20° C.	50° C.		
Aluminum	0.76	—0.0039	0.68	0.56	195	T
Antimony, comm'l pressed wire	–	–	—6.0	–	–	M
" axial	–	–	—22.6	–	–	"
" equatorial	–	–	—26.4	–	–	"
" ordinary	–	–	—17.0	–	–	B
Argentan	11.94	0.0506	12.95	14.47	—236	T
"	–	–	–	12.7	–	B
Arsenic	–	–	13.56	–	–	M
Bismuth, comm'l pressed wire	–	–	97.0	–	–	"
" pure " "		–	89.0	–	–	"
" crystal, axial	–	–	65.0	–	–	"
" " equatorial	–	–	45.0	–	–	"
" commercial		–	–	39.9	–	B
Cadmium	—2.63	—0.0424	—3.48	—4.75	—62	T
" fused	–	–	–	—2.45	–	B
Cobalt	–	–	22.	–	–	M
Constantin	–	–	–	+19.3	–	–
Copper	—1.34	—0.0094	—1.52	—1.81	—143	T
" commercial	–	–	—0.10	–	–	M
" galvanoplastic	–	–	—3.8	–	–	"
Gold	–	–	—1.2	–	–	"
"	—2.80	—0.0101	—3.0	—3.30	[—277]	T
Iron	—17.15	0.0482	—16.2	—14.74	356	"
" pianoforte wire	–	–	—17.5	–	–	M
" commercial	–	–	–	—12.10	–	B
" "	–	–	–	—9.10	–	"
Lead	–	0.0000	0.00	0.00	–	–
Magnesium	—2.22	0.0094	—2.03	—1.75	236	T
Mercury	–	–	0.413	–	–	M
"	–	–	–	3.30	–	B
Nickel	–	–	–	15.50	–	"
" (—18° to 175°)	21.8	0.0506	22.8	24.33	[—431]	T
" (250°–300°)	83.57	—0.2384	–	–	–	"
" (above 340°)	3.04	0.0506	–	–	–	"

TABLE 298.—Thermoelectric Power (*continued*).

Substance.	A Microvolts.	B Microvolts.	Thermoelectric power at mean temp. of junctions (microvolts). 20° C.	50° C.	Neutral point $-\frac{A}{B}$.	Authority.
Palladium	6.18	0.0355	6.9	7.96	—174	T
"	–	–	–	6.9	–	B
Phosphorus (red)	–	–	—29.9	–	–	M
Platinum	–	–	—0.9	–	–	"
" (hardened)	—2.57	0.0074	—2.42	—2.20	347	T
" (malleable)	0.60	0.0109	8.82	1.15	—55	"
" wire	–	–	–	—0.94	–	B
" another specimen	–	–	–	2.14	–	"
Platinum-iridium alloys:						
85 % Pt+15 % Ir	—7.90	—0.0062	—8.03	—8.21	[—1274]	T
90 % Pt+10 % Ir	—5.90	0.0133	—5.63	—5.23	444	"
95 % Pt + 5 % Ir	—6.15	—0.0055	—6.26	—6.42	[—1118]	"
Selenium	–	–	—807.	–	–	M
Silver	—2.12	—0.0147	—2.41	—2.86	—144	T
" (pure hard)	–	–	—3.00	–		M
" wire	–	–	–	—2.18		B
Steel	—11.27	0.0325	—10.62	—9.65	347	T
Tellurium	–	–	—502.	–	–	M
"	–	–	–	—429.3	–	B
Tellurium β	–	–	—500.	–	–	H
" α	–	–	—160.	–	–	H
Tin (commercial)	–	–	–	—0.33	–	"
"	–	–	—0.1	–	.	M
"	0.43	—0.0055	0.33	0.16	78	T
Zinc	—2.32	—0.0238	—2.79	—3.51	—98	"
" pure pressed	–	–	—3.7	–	–	M

B Ed. Becquerel, "Ann. de Chim. et de Phys." [4] vol. 8.
M Matthiesen, "Pogg. Ann." vol. 103, reduced by Fleming Jenkin.
T Tait, "Trans. R. S. E." vol. 27, reduced by Mascart.
B Haken, Ann. der Phys. 32, p. 291, 1910. (Electrical conductivity of Teβ = 0.04, Teα 1.7 e. m. units.)

TABLE 299.—Thermoelectric Power of Alloys.

The thermoelectric powers of a number of alloys are given in this table, the authority being Ed. Becquerel. They are relative to lead, and for a mean temperature of 50° C. In reducing the results from copper as a reference metal, the thermoelectric power of lead to copper was taken as — 1.9.

Substance.	Relative quantity.	Thermoelectric power in microvolts.	Substance.	Relative quantity.	Thermoelectric power in microvolts.	Substance.	Relative quantity.	Thermoelectric power in microvolts.
Antimony Cadmium	806 696	227	Antimony Zinc Tin	2 1 1	43	Bismuth Antimony	4 1	—51.4
Antimony Cadmium Zinc	4 2 1	146	Antimony Cadmium Zinc	12 10 3	35	Bismuth Antimony	8 1	—63.2
Antimony Cadmium Bismuth	806 696 121	137	Antimony Tellurium	10 1	10.2	Bismuth Antimony	10 1	—68.2
Antimony Zinc	806 406	95	Antimony Bismuth	10 1	8.8	Bismuth Antimony	12 1	—66.9
Antimony Zinc Bismuth	806 406 121	8.1	Antimony Iron	4 1	2.5	Bismuth Tin	2 1	60
Antimony Cadmium Lead Zinc	4 2 1 1	76	Antimony Magnesium	8 1	1.4	Bismuth Selenium	10 1	—24.5
Antimony Cadmium Zinc Tin	4 2 1 1	46	Antimony Lead	8 1	—0.4	Bismuth Zinc	12 1	—31.1
			Bismuth	–	—43.8	Bismuth Arsenic	12 1	—46.0
			Bismuth Antimony	2 1	—33.4	Bismuth Bismuth sulphide	1 1	68.1

TABLE 300.—Thermoelectric Power against Platinum.

One junction is supposed to be at 0° C; + indicates that the current flows from the 0° junction into the platinum. The rhodium and iridium were rolled, the other metals drawn.*

Temperature, °C.	Au.	Ag.	90%Pt+10%Pd.	10%Pt+90%Pd.	Pd.	90%Pt+10%Rh.	90%Pt+10%Ru.	Ir.	Rh.
—185	—0.15	—0.16	—0.11	+0.24	+0.77	-	—0.53	—0.28	—0.24
—80	—0.31	—0.30	—0.09	+0.15	+0.39	-	—0.39	—0.32	—0.31
+100	+0.74	+0.72	+0.26	—0.19	—0.56	-	+0.73	+0.65	+0.65
+200	+1.8	+1.7	+0.62	—0.31	—1.20	-	+1.6	+1.5	+1.5
+300	+3.0	+3.0	+1.0	—0.37	—2.0	+2.3	+2.6	+2.5	+2.6
+400	+4.5	+4.5	+1.5	—0.35	—2.8	+3.2	+3.6	+3.6	+3.7
+500	+6.1	+6.2	+1.9	—0.18	—3.8	+4.1	+4.6	+4.8	+5.1
+600	+7.9	+8.2	+2.4	+0.12	—4.9	+5.1	+5.7	+6.1	+6.5
+700	+9.9	+10.6	+2.9	+0.61	—6.3	+6.2	+6.9	+7.6	+8.1
+800	+12.0	+13.2	+3.4	+1.2	—7.9	+7.2	+8.0	+9.1	+9.9
+900	+14.3	+16.0	+3.8	+2.1	—9.6	+8.3	+9.2	+10.8	+11.7
+1000	+16.8	-	+4.3	+3.1	—11.5	+9.5	+10.4	+12.6	+13.7
+1100	-	-	+4.8	+4.2	—13.5	+10.6	+11.6	+14.5	+15.8
+(1300)	-	-	-	-	-	+13.1	+14.2	+18.6	+20.4
+(1500)	-	-	-	-	-	+15.6	+16.9	+23.1	+25.6

* Holborn and Day.

TABLE 301.—Thermal E. M. F. of Pure Platinum Against Platinum-Rhodium Alloys, in Millivolts.*

t	1 p. ct.	5 p. ct.	10 p. ct.			15 p. ct.	20 p. ct.	30 p. ct.†	40 p. ct.†	100 p. ct.‡
			Low.	High.	Standard.					
100°	0.21	0.55	0.63	0.64	0.64	0.65	....	....	....	0.65
200	0.42	1.18	1.41	1.43	1.43	1.50	....	....	....	1.51
300	0.63	1.85	2.28	2.32	2.32	2.41	....	2.34	2.45	2.57
400	0.84	2.53	3.21	3.26	3.25	3.45	3.50	3.50	3.64	3.76
500	1.05	3.22	4.17	4.23	4.23	4.55	4.60	4.74	4.93	5.08
600	1.25	3.92	5.16	5.24	5.23	5.71	5.83	6.06	6.31	6.55
700	1.45	4.62	6.19	6.28	6.27	6.94	7.18	7.49	7.80	8.14
800	1.65	5.33	7.25	7.35	7.33	8.23	8.60	9.01	9.37	9.87
900	1.85	6.05	8.35	8.46	8.43	9.57	10.09	10.67	11.09	11.74
1000	2.05	6.79	9.47	9.60	9.57	10.96	11.65	12.42	12.94	13.74
1100	2.25	7.53	10.64	10.77	10.74	12.40	13.29	14.33	14.99	15.87
1200	2.45	8.29	11.82	11.97	11.93	13.87	14.96	16.39	17.13	18.10
1300	2.65	9.06	13.02	13.18	13.13	15.38	16.65	18.51	19.51	20.46
1400	2.86	9.82	14.22	14.39	14.34	16.98	18.39	20.67	21.73	....
1500	3.06	10.56	15.43	15.61	15.55	18.41	20.15	....	....	....
1600	3.26	11.31	16.63	16.82	16.75	19.94	21.90	....	....	....
1700	3.46	12.05	17.83	18.03	17.95	21.47	23.65	....	....	....
1755	3.56	12.44	18.49	18.70	18.61	22.31	24.55	....	....	....

* Carnegie Institution, Pub. 157, 1911.
† Holborn and Wien, 1892.
‡ Holborn and Day, mean value, 1899.

TABLE 302. — Peltier Effect.

The coefficient of Peltier effect may be calculated from the constants *A* and *B* of Table 298, as there shown. Experimental results, expressed in slightly different units, are here given. The figures are for the heat production at a junction of copper and the metal named, in calories per ampere-hour. The current flowing from copper to the metal named, a positive sign indicates a warming of the junction. The temperature not being stated by either author, and Le Roux not giving the algebraic signs, these results are not of great value.

	Calories per ampere-hour.										
	Sb. ‡	Sb. commercial.	Bi. pure.	Bi. §	Cd.	German Silver.	Fe.	Ni.	Pt.	Ag.	Zn.
Jahn* . .	-	-	-	-	—.62	-	—3.61	4.36	0.32	—.41	—.58
Le Roux† .	13.02	4.8	19.1	25.8	0.46	2.47	2.5	-	-	-	.39

* "Wied. Ann." vol. 34, p. 767.
† "Ann. de Chim. et de Phys." (4) vol. 10, p. 201.
‡ Becquerel's antimony is 806 parts Sb + 406 parts Zn + 121 parts Bi.
§ Becquerel's bismuth is 10 parts Bi + 1 part Sb.

TABLE 303. — Peltier Effect, Fe-Constantan, Ni-Cu, 0 — 560° C.

Temperature.	0°	20°	130°	240°	320°	560°	
Fe-Constantan . . .	3.1	3.6	4.5	6.2	8.2	12.5	in Gram. Cal. $\times 10^{-8}$
Ni-Cu	1.92	2.15	2.45	2.06	1.91	2.38	per coulomb.

TABLE 304. — Peltier Electromotive Force in Millivolts.

Metal against Copper.	Sb.	Fe.	Cd.	Zn.	Ag.	Au.	Pb.	Sn.	Al.	Pt.	Pd.	Ni.	Bi.
Le Roux .	—5.64	—2.93	—.53	—.45						-			+22.3
Jahn . . .		—3.68	—.72	—.68	—.48					+.37	-	+5.07	
Edlund . .		—2.96	—.16	—.01	+.03	+.33	+.50	+.56	+.70	+1.02	+2.17	-	+17.7
Caswell . .	-		-	-	+.03		-	-	+.70	+.85	-	+6.0	+16.1

Le Roux, 1867; Jahn, 1888; Edlund, 1870-71; Caswell, Phys. Rev. 33, p. 381, 1911.

TABLE 305.

VARIOUS DETERMINATIONS OF THE VALUE OF THE OHM.

Date.	Observer.	Method.	Value of B. A. unit in ohms.	Value of Siemens unit, B. A. unit.	Value of ohm in cms. of Hg.
1882	Lord Rayleigh .	Rotating coil . .	0.98651	0.95412	106.24
1883	Lord Rayleigh .	Lorenz method . .	.98677	.95412	106.21
1884	Mascart . . .	Induced current . .	.98611	.95374	106.33
1887	Rowland . . .	Mean of several methods	.98644	.95349	106.32
1887	Kohlrausch . .	Damping of magnets .	.98660	.95338	106.32
1882 } 1888 }	Glazebrook . .	Induced currents . .	.98665	.95352	106.29
1890	Wuilleumeier . .	Mean effect of induced currents . . .	.98686	.95355	106.31
1890	Duncan and Wilkes	Lorenz method . .	.98634	.95341	106.34
1891	Jones . . .	Lorenz method . .	–	–	106.31
1894	Jones . . .	Lorenz method . .	–	–	106.33
1895	Himstedt . .	Mean effect of induced current . . .	–	–	106.28
1897	Ayrton and Jones .	Lorenz method . .	(.98634)	–	106.27
1899	Guillet . . .	Mean effect of induced current, using a calibrated 1000-ohm coil . . .		–	106.20
		Means . . .	0.98651	0.95366	106.288
1883	Wild . . .	Damping of magnet .	–	–	106.03
1884	Wiedemann . .	Earth inductor . .	–	–	106.19
1884	H. F. Weber . .	Induced current . .	–	–	105.37
1884	H. F. Weber . .	Rotating coil . . .	–	–	106.16
1884	Roiti . . .	Mean effect of induced current, using German silver coils certified by makers		–	105.89
1885	Himstedt . .	Mean effect of induced current, using German silver coils certified by makers		–	105.98
1885	Lorenz . . .	Lorenz method . .	–	–	105.93
1889	Dorn . . .	Damping of magnet .	–	–	106.24
1911	Nat. Phys. Lab. .	2 phase	–	–	106.27

The legal value of the ohm is the resistance of a column of mercury of uniform cross-section, weighing 14.4521 gms., and having a length of 106.30 cms. This is known as the international ohm. Mercury ohms conforming to these specifications have been prepared in recent years at the Physikalisch-Technische Reichsanstalt, the National Physical Laboratory, and the Bureau of Standards. The wire standards of resistance at the above-named laboratories agree in value to within two parts in 100000. Hence there is a very close agreement in the values of precision resistances calibrated at these laboratories.

SPECIFIC RESISTANCE OF METALLIC WIRES.

This table is modified from the table compiled by Jenkin (1862) from Matthiessen's results by taking the resistance of silver, gold, and copper from the observed metre gramme value and assuming the densities found by Matthiessen, namely, 10.468, 19.265, and 8.95.

Substance.	Resistance at 0° C. of a wire one cm. long, one sq. cm. in section.	Resistance at 0° C. of a wire one metre long, one mm. in diam.	Resistance at 0° C. of a wire one metre long, weighing one gram.	Resistance at 0° C. of a wire one foot long, 1/1000 in. in diam.	Resistance at 0° C. of a wire one foot long, weighing one grain.	Percentage increase of resistance for 1° C. increase of temp. at 20° C.
Silver annealed . . .	1.460×10^{-6}	0.01859	.1523	8.781	.2184	0.377
" hard drawn . .	1.585 "	0.02019	.1659	9.538	.2379	–
Copper annealed . .	1.584 "	0.02017	.1421	9.529	.2037	0.388
" hard drawn . .	1.619 "	0.02062	.1449	9.741	.2078	–
Gold annealed . . .	2.088 "	0.02659	.4025	12.56	.5771	0.365
" hard drawn . .	2.125 "	0.02706	.4094	12.78	.5870	–
Aluminium annealed . .	2.906 "	0.03699	.0747	17.48	.1071	–
Zinc pressed . . .	5.613 "	0.07146	.4012	33.76	.5753	0.365
Platinum annealed . .	9.035 "	0.1150	1.934	54.35	2.772	–
Iron " . .	9.693 "	0.1234	.7551	58.31	1.083	–
Nickel " . .	12.43 "	0.1583	1.057	74.78	1.515	–
Tin pressed . . .	13.18 "	0.1678	.9608	79.29	1.377	0.365
Lead " . . .	19.14 "	0.2437	2.227	115.1	3.193	0.387
Antimony pressed . .	35.42 "	0.4510	2.379	213.1	3.410	0.389
Bismuth " . .	130.9 "	1.667	12.86	787.5	18.43	0.354
Mercury " . .	94.07 "	1.198	12.79	565.9	18.34	0.072
Platinum-silver, 2 parts Ag, 1 part Pt, by weight .	24.33 "	0.3098	2.919	146.4	4.186	0.031
German silver . . .	20.89 "	0.2660	1.825	125.7	2.617	0.044
Gold-silver, 2 parts Au, 1 part Ag, by weight .	10.84 "	0.1380	1.646	65.21	2.359	0.065

Table 307.

SPECIFIC RESISTANCE OF METALS.

The resistance is here given as the resistance in microhms per cm. cube when the specific resistance of mercury at 0° is taken as 94.1 microhms.

Substance.	State.	Temperature, °C.	Resistance.	Authority.
Aluminum . . .	c. p.	—189.	0.64	Niccolai, 1907.
"	"	—100.	1.53	" "
"	"	0.	2.62	" "
"	"	+100.	3.86	" "
"	"	400.	8.0	" "
"		20.	2.828	See p. 284.
Antimony . . .		—190.	10.5	Eucken, Gelhoff.
"		0.	38.6	Mean.
"	liquid	+860.	120.	de la Rive.
Arsenic		0.	35.	Matthiessen.
Bismuth . . .		18.	119.0	Jäger, Diesselhorst.
"		100.	160.2	" "
Cadmium . . .	drawn	—160.	2.72	Lees, 1908.
"	"	18.	7.54	Jäger, Diesselhorst.
"	"	100.	9.82	" "
"	liquid	318.	34.1	Mean.
Cæsium		—187.	5.25	Guntz, Broniewski.
"		0.	19.	Mean.
Calcium . . .	99.5 pure	20.	10.5	Moissan, Chavanne
Chromium . . .		0.	2.6	Shukow.
Cobalt	99.8 pure	20.	9.7	Reichardt, 1901.
Copper	annealed	20.	1.724	See p. 284.
"	hard-drawn	20.	1.77	" "
"	electrolytic	—206.	.144	Dewar, Fleming,
"	"	+205.	2.92	Dickson.
"	pure	400.	4.10	Niccolai, 1907.
Gallium		0.	53.	Guntz, Broniewski.
Gold	99.9 pure	—183.	0.68	D, F, D, 1898.
"		0.	2.22	Mean.
"	pure, drawn	18.	2.42	J, D, 1900.
"	99.9 pure	194.5	3.77	D, F, D, 1898.
Indium		0.	8.37	Erhardt, 1881.
Iridium		—186.	1.92	Broniewski, Hack-
"		0.	6.10	spill, 1911.
"		+100.	8.3	" "
Iron	pure, soft	—205.3	.652	D, F, D, 1898.
"	" "	—78.	5.32	" " " "
"	" "	0.	8.85	" " " "
"	" "	+98.5	17.8	" " " "
"	" "	196.1	21.5	" " " "
"	"	400.	43.3	Niccolai, 1907.
—steel . . .	cast	ord.	19.1	Kohlrausch.
"	"	yel. ht.	104.	"
"	"	wh. ht.	114.	"
"	piano-wire	0.	11.8	Strouhal, Barus, '83.
"	temp. glass, hard	0.	45.7	" " "
"	" " yellow	0.	27.	" " "
"	" " blue	0.	20.5	" " "
"	" " soft	0.	15.9	" " "
Lead	cold-pressed	—183.	6.02	D, F, D, 1898.
"	" "	— 78.	14.1	" " " "
"	" "	0.	20.4	" " " "
"	" "	90.4	28.0	" " " "
"		196.1	36.9	" " " "
"		318.	94.	Vincentini, Omodei.
Lithium	solid	—187.	1.34	Guntz, Broniewski.

SPECIFIC RESISTANCE OF METALS.

The resistance is here given as the resistance in microhms per cm. cube when the specific resistance of mercury at 0° C is taken as 94.1 microhms.

Substance.	State.	Temperature, °C.	Resistance.	Authority.
Lithium, continued		0.	8.55	Guntz, Broniewski.
" "		99.3	12.7	" "
" "	liquid	230.	45.2	Bernini, 1905.
Manganese . . .			5.0±	Shukow.
Magnesium . . .	free from zn.	—183.	1.00	Dewar, Fleming,
"	" " "	— 78.	2.97	Dickson, 1898.
"	" " "	0.	4.35	D, F, D, 1898.
"	" " "	98.5	5.99	" " " "
"	pure	400.	11.9	Niccolai, 1907.
Mercury	solid	—183.5	6.97	D, F, D, 1898.
"	"	—147.5	10.57	" "
"	"	—102.9	15.04	" "
"	"	— 50.3	21.3	" "
"	"	— 39.2	25.5	" "
"	"	— 36.1	80.6	" "
"	liquid	0.0	94.07	" "
"	"	10.	94.92	Strecker, 1885.
"	"	20.	95.74	" "
"	"	50.	98.50	Grimaldi, 1888.
"	"	100.	103.25	Vincentini, Omodei,
"	"	200.	114.27	1890.
"	"	350.	135.5	"
Nickel	pure	—182.5	1.44	Fleming, 1900.
"	"	— 78.2	4.31	" "
"	"	0.	6.93	" "
"	"	94.9	11.1	" "
"		400.	60.2	Niccolai, 1907.
Osmium		20.	9.5	Blau, 1905.
Palladium . . .	very pure	—183.	2.78	Dewar, Fleming,'96
"	" "	— 78.	7.17	" " "
"	" "	0.	10.21	" " "
"	" "	98.5	13.79	" " "
Platinum	wire	—203.1	2.44	D, F, D.
"	"	— 97.5	6.87	" " "
"	"	0.	10.96	" " "
"	"	100.	14.85	" " "
"		400.	26.0	Niccolai, 1907.
Rhodium . . .		—186.	0.70	Broniewski, Hack-
"		— 78.3	3.09	spill, 1911.
"		0.	4.69	" "
"		100.	6.60	" "
Rubidium . . .	solid	—190.	2.5	Hackspill, 1910.
"	"	0.	11.6	" "
"	liquid	40.	19.6	" "
Silver	electrolytic	—183.	0.390	D, F, D, 1898.
"	"	— 78.	1.021	" " " "
"	"	0.	1.468	" " " "
"	"	98.15	2.062	" " " "
"	"	192.1	2.608	" " " "
"	"	400.	3.77	Niccolai, 1907.
"	999.8 pure	18.	1.629	Jäger, Diesselhorst
Silicium		—	58.±	—
Strontium . . .		20.	24.8	Matthiessen, 1857.
Sodium	solid	—178.	0.80	Guntz, Broniewski,
"	"	— 78.3	2.86	1909.
"	"	0.	4.48	"
"	"	50.	5.32	"

SPECIFIC RESISTANCE OF METALS.

TABLE 307 (*concluded*).

The resistance is here given as the resistance in microhms per cm. cube when the specific resistance of mercury at 0° C. is taken as 94.1 microhms.

Substance.	State.	Temperature, C.	Resistance.	Authority.
Tantalum	Pure		14.6	Pirani.
Tellurium	–	19.6°	21.5	Matthiessen, 1852.
Thallium	Pure	−183.	4.08	Dewar, Fleming, Dickson, 1898.
"	"	− 78.	11.8	" " " "
"	"	0.	17.60	" " " "
"	"	98.5	24.7	" " " "
Titanium		–	3.19	Shukow.
Tin	–	−183.	3.40	D, F, D, 1898.
"	–	− 78.	8.8	" " " "
"	–	0.	13.0	" " " "
"	–	91.45	18.2	" " " "
"		176.	23.6	" " " "
Zinc	Trace Fe	−183.	1.62	" " " "
"	" "	− 78.	3.34	" " " "
"	" "	0.	5.75	" " " "
"	" "	92.45	8.00	" " " "
"	" "	191.5	10.37	" " " "
"	Liquid	440.	37.2	De la Rive, 1863.

TABLE 308.—Temperature Resistance Coefficients.

If R_0 is the resistance at the temperature t_0, and R_t at the temperature t, then R_t may over small ranges of temperature be approximately represented by the formula $R_t = R_0 (1 + at)$.

Substance.	Temperature.	a.	See at foot.	Substance.	Temperature.	a.	See at foot.
Aluminum	18–100° C.	0.0039	1	Nickel	0–100° C.	0.0062	3
"	$t_0 = 25°$	.0034	2	"	$t_0 = 25°$	0.0043	2
"	100	.0040	"	"	100	.0043	"
"	500	.0050	"	"	500	.0030	"
Bismuth	0–100	.00458	–	"	1000	.0037	"
Cadmium	0–100	.0042	–	Palladium	0–100	.0035	3
Copper	see p. 284–85	.0040	–	Platinum	0–100	.0037	"
"	$t_0 = 100°$	.0038	2	Silver	0–100	.0040	"
"	400	.0042	"	"	$t_0 = 25°$	.0030	2
"	1000	.0062	"	"	100	.0036	"
Gold	18–100	.00368	1	"	500	.0044	"
" annealed	$t_0 = 100°$	.0025	2	Tantalum	0–100	.0033	6
" "	500	.0035	"	Tin	18–100	.0046	1
" "	1000	.0049	"	Tungsten	18–100	.0045	"
Iron, pure	0–100	.0062	3	"	$t_0 = 500°$	.0057	2
" "	$t_0 = 25°$	.0052	2	"	1000	.0089	"
" "	100	.0068	"	Zinc	0–100	.0040	3
" "	500	.0147	"				
" "	1000	.0050	"	Advance	$t_0 = 12°$	+.000020	2
— steel	glass, h'd	.0016	4	"	50	−.000008	"
"	blue	.0033	"	"	100	−.000007	"
"	piano wire	.0032	"	"	200	+.000007	"
Lead	18–100	.0043	1	Constantin	12	+.000008	"
Magnesium	0–100	.0038	3	"	25	+.000002	"
"	$t_0 = 25°$	.0050	2	"	100	−.000033	"
"	100	.0045	"	"	200	−.000020	"
"	500	.0036	"	"	500	+.000027	"
"	600	.0100	"	Manganin	12	+.000006	"
Mercury*	0–15	.00088	5	"	25	.000000	"
Molybdenum	$t_0 = 25°$	.0033	2	"	100	−.000042	"
"	100	.0034	"	"	250	−.000052	"
"	500	.0050	"	"	475	.000000	"
"	1000	.0048	"	"	500	−.000110	"

1, Jäger, Diesselhorst, Wiss. Abh. D., Phys. Tech. Reich. 3, p. 269, 1900; 2, Somerville, Phys. Rev. 31, p. 261, 1910, 33, p. 77, 1911; 3, Dewar, Fleming, 1893, 1896; Strouhal, Barus, 1883; 5, Glazebrook Phil. Mag. 20, p. 343, 1885; 6, Pirani.

* Mercury, $R = R_0 (1 + .00089t + .000001t^2)$.

TABLE 309.

CONDUCTIVITY OF THREE-METAL AND MISCELLANEOUS ALLOYS.

Conductivity in mhos or $\frac{1}{\text{ohms per cm. cube}} = C_t = C_0\,(1 - at + bt^2)$.

Metals and alloys.	Composition by weight.	$\frac{C_0}{10^4}$	$a \times 10^6$	$b \times 10^9$	Authority.
Gold-copper-silver . . .	58.3 Au + 26.5 Cu + 15.2 Ag	7.58	574	924	1
" " " . . .	66.5 Au + 15.4 Cu + 18.1 Ag	6.83	529	93	1
" " " . . .	7.4 Au + 78.3 Cu + 14.3 Ag	28.06	1830	7280	1
Nickel-copper-zinc . . .	{ 12.84 Ni + 30.59 Cu + 6.57 Zn by volume . . . }	4.92	444	51	1
Brass	Various	12.2–15.6	$1-2 \times 10^8$	–	2
" hard drawn . . .	70.2 Cu + 29.8 Zn	12.16	–	–	3
" annealed	" "	14.35	–	–	3
German silver	Various	3–5	–	–	2
" "	{ 60.16 Cu + 25.37 Zn + 14.03 Ni + .30 Fe with trace of cobalt and manganese . }	3.33	360	–	4
Aluminum bronze . . .	– – –	7.5–8.5	$5-7 \times 10^2$	–	2
Phosphor bronze . . .	– – –	10–20	–	–	2
Silicium bronze	– – –	41	–	–	5
Manganese-copper . . .	30 Mn + 70 Cu	1.00	40	–	4
Nickel-manganese-copper	3 Ni + 24 Mn + 73 Cu . .	2.10	—30	–	4
Nickelin	{ 18.46 Ni + 61.63 Cu + 19.67 Zn + 0.24 Fe + 0.19 Co + 0.18 Mn . . . }	3.01	300	–	4
Patent nickel	{ 25.1 Ni + 74.41 Cu + 0.42 Fe + 0.23 Zn + 0.13 Mn + trace of cobalt }	2.92	190	–	4
Rheotan	{ 53.28 Cu + 25.31 Ni + 16.89 Zn + 4.46 Fe + 0.37 Mn . . . . }	1.90	410	–	4
Copper-manganese-iron .	91 Cu + 7.1 Mn + 1.9 Fe .	4.98	120	–	6
" " " .	70.6 Cu + 23.2 Mn + 6.2 Fe	1.30	22	–	6
" " " .	69.7 Cu + 29.9 Ni + 0.3 Fe .	2.60	120	–	7
Manganin	84 Cu + 12 Mn + 4 Ni . . .	2.3	6	–	2
Constantan	60 Cu + 40 Ni	2.04	8	–	7

1 Matthiessen. 2 Various. 3 W. Siemens. 4 Feussner and Lindeck. 5 Van der Ven. 6 Blood. 6 Feussner. 7 Jaeger-Diesselhorst.

TABLE 310.

CONDUCTING POWER OF ALLOYS.

This table shows the conducting power of alloys and the variation of the conducting power with temperature.* The values of C_0 were obtained from the original results by assuming silver $= \frac{10^6}{1.585}$ mhos. The conductivity is taken as $C_t = C_0 (1 - at + bt^2)$, and the range of temperature was from 0° to 100° C.

The table is arranged in three groups to show (1) that certain metals when melted together produce a solution which has a conductivity equal to the mean of the conductivities of the components, (2) the behavior of those metals alloyed with others, and (3) the behavior of the other metals alloyed together.

It is pointed out that, with a few exceptions, the percentage variation between 0° and 100° can be calculated from the formula $P = P_c \frac{l}{l'}$, where l is the observed and l' the calculated conducting power of the mixture at 100° C., and P_c is the calculated mean variation of the metals mixed.

Alloys.	Weight % of first named.	Volume % of first named.	$\frac{C_0}{10^4}$	$a \times 10^6$	$b \times 10^9$	Variation per 100° C. Observed.	Variation per 100° C. Calculated.
Group 1.							
Sn_6Pb	77.04	83.96	7.57	3890	8670	30.18	29.67
Sn_4Cd	82.41	83.10	9.18	4080	11870	28.89	30.03
SnZn	78.06	77.71	10.56	3880	8720	30.12	30.16
PbSn	64.13	53.41	6.40	3780	8420	29.41	29.10
$ZnCd_2$	24.76	26.06	16.16	3780	8000	29.86	29.67
$SnCd_4$	23.05	23.50	13.67	3850	9410	29.08	30.25
$CdPb_6$	7.37	10.57	5.78	3500	7270	27.74	27.60
Group 2.							
Lead-silver ($Pb_{20}Ag$)	95.05	94.64	5.60	3630	7960	28.24	19.96
Lead-silver (PbAg)	48.97	46.90	8.03	1960	3100	16.53	7.73
Lead-silver ($PbAg_2$)	32.44	30.64	13.80	1990	2600	17.36	10.42
Tin-gold ($Sn_{12}Au$)	77.94	90.32	5.20	3080	6640	24.20	14.83
" " (Sn_5Au)	59.54	79.54	3.03	2920	6300	22.90	5.95
Tin-copper	92.24	93.57	7.59	3680	8130	28.71	19.76
" " †	80.58	83.60	8.05	3330	6840	26.24	14.57
" " †	12.49	14.91	5.57	547	294	5.18	3.99
" " †	10.30	12.35	6.41	666	1185	5.48	4.46
" " †	9.67	11.61	7.64	691	304	6.60	5.22
" " †	4.96	6.02	12.44	995	705	9.25	7.83
" " †	1.15	1.41	39.41	2670	5070	21.74	20.53
Tin-silver	91.30	96.52	7.81	3820	8190	30.00	23.31
" "	53.85	75.51	8.65	3770	8550	29.18	11.89
Zinc-copper †	36.70	42.06	13.75	1370	1340	12.40	11.29
" " †	25.00	29.45	13.70	1270	1240	11.49	10.08
" " †	16.53	23.61	13.44	1880	1800	12.80	12.30
" " †	8.89	10.88	29.61	2040	3030	17.41	17.42
" " †	4.06	5.03	38.09	2470	4100	20.61	20.62

NOTE. — Barus, in the "Am. Jour. of Sci." vol. 36, has pointed out that the temperature variation of platinum alloys containing less than 10% of the other metal can be nearly expressed by an equation $y = \frac{n}{x} - m$, where y is the temperature coefficient and x the specific resistance, m and n being constants. If a be the temperature coefficient at 0° C. and s the corresponding specific resistance, $s(a + m) = n$.

For platinum alloys Barus's experiments gave $m = -.000194$ and $n = .0378$.
For steel $m = -.000303$ and $n = .0620$.

Matthiessen's experiments reduced by Barus gave for

Gold alloys $m = -.000045$, $n = .00721$.
Silver " $m = -.000112$, $n = .00538$.
Copper " $m = -.000386$, $n = .00055$.

* From the experiments of Matthiessen and Vogt, "Phil. Trans. R. S." v. 154.
† Hard-drawn.

TABLE 310. — Conducting Power of Alloys.

Alloys.	Weight % of first named.	Volume % of first named.	$\frac{C_0}{10^4}$	$a \times 10^6$	$b \times 10^9$	Variation per 100° C. Observed.	Variation per 100° C. Calculated.
Group 3.							
Gold-copper †	99.23	98.36	35.42	2650	4650	21.87	23.22
" " †	90.55	81.66	10.16	749	81	7.41	7.53
Gold-silver †	87.95	79.86	13.46	1090	793	10.09	9.65
" " *	87.95	79.86	13.61	1140	1160	10.21	9.59
" " †	64.80	52.08	9.48	673	246	6.49	6.58
" " *	64.80	52.08	9.51	721	495	6.71	6.42
" " †	31.33	19.86	13.69	885	531	8.23	8.62
" " *	31.33	19.86	13.73	908	641	8.44	8.31
Gold-copper †	34.83	19.17	12.94	864	570	8.07	8.18
" " †	1.52	0.71	53.02	3320	7300	25.90	25.86
Platinum-silver †	33.33	19.65	4.22	330	208	3.10	3.21
" " †	9.81	5.05	11.38	774	656	7.08	7.25
" " †	5.00	2.51	19.96	1240	1150	11.29	11.88
Palladium-silver †	25.00	23.28	5.38	324	154	3.40	4.21
Copper-silver †	98.08	98.35	56.49	3450	7990	26.50	27.30
" " †	94.40	95.17	51.93	3250	6940	25.57	25.41
" " †	76.74	77.64	44.06	3030	6070	24.29	21.92
" " †	42.75	46.67	47.29	2870	5280	22.75	24.00
" " †	7.14	8.25	50.65	2750	4360	23.17	25.57
" " †	1.31	1.53	50.30	4120	8740	26.51	29.77
Iron-gold †	13.59	27.93	1.73	3490	7010	27.92	14.70
" " †	9.80	21.18	1.26	2970	1220	17.55	11.20
" " †	4.76	10.96	1.46	487	103	3.84	13.40
Iron-copper †	0.40	0.46	24.51	1550	2090	13.44	14.03
Phosphorus-copper †	2.50	-	4.62	476	145	-	-
" " †	0.95	-	14.91	1320	1640	-	-
Arsenic-copper †	5.40	-	3.97	516	989	-	-
" " †	2.80	-	8.12	736	446	-	-
" " †	trace	-	38.52	2640	4830	-	-

* Annealed. † Hard-drawn.

TABLE 311. — Allowable Carrying Capacity of Rubber-covered Copper Wires.

(For inside wiring — Nat. Board Fire Underwriters' Rules.)

B + S Gage	18	16	14	12	10	8	6	5	4	3	2	1	0	00	0000
Amperes	3	6	12	17	24	33	46	54	65	76	90	107	127	150	210

500,000 circ. mills, 390 amp.; 1,000,000 c. m., 650 amp.; 2,000,000 c. m., 1,050 amp. For insulated al. wire, capacity = 84% of cu. Preece gives as formula for fusion of bare wires $I = ad^{\frac{3}{2}}$, where d = diam. in inches, a for cu. is 10,244; al., 7585; pt., 5172; German silver, 5230; platinoid, 4750; Fe, 3148; Pb., 1379; alloy 2 pts. Pb., 1 of Sn., 1318.

RESISTANCE OF METALS AND

The electrical resistance of some pure metals and of some alloys have been determined by Dewar and Fleming and increases as the temperature is lowered. The resistance seems to approach zero for the pure metals, but not for temperature tried. The following table gives the results of Dewar and Fleming.*

When the temperature is raised above 0° C. the coefficient decreases for the pure metals, as is shown by the experi- experiments to be approximately true, namely, that the resistance of any pure metal is proportional to its absolute is greater the lower the temperature, because the total resistance is smaller. This rule, however, does not even zero Centigrade, as is shown in the tables of resistance of alloys. (Cf. Table 262.)

Temperature =	100°	20°	0°	—80°
Metal or alloy.	Specific resistance in c. g. s. units.			
Aluminium, pure hard-drawn wire	4745	3505	3161	-
Copper, pure electrolytic and annealed	1920	1457	1349	-
Gold, soft wire	2665	2081	1948	1400
Iron, pure soft wire	13970†	9521	8613	-
Nickel, pure (prepared by Mond's process from compound of nickel and carbon monoxide)	19300	13494	12266	7470
Platinum, annealed	10907	8752	8221	6133
Silver, pure wire	2139	1647	1559	1138
Tin, pure wire	13867	10473	9575	6681
German silver, commercial wire	35720	34707	34524	33664
Palladium-silver, 20 Pd + 80 Ag	15410	14984	14961	14482
Phosphor-bronze, commercial wire	9071	8588	8479	8054
Platinoid, Martino's platinoid with 1 to 2% tungsten	44590	43823	43601	43022
Platinum-iridium, 80 Pt + 20 Ir	31848	29902	29374	27504
Platinum-rhodium, 90 Pt + 10 Rh	18417	14586	13755	10778
Platinum-silver, 66.7 Ag + 33.3 Pt	27404	26915	26818	26311
Carbon, from Edison-Swan incandescent lamp	-	4046×10^8	4092×10^8	4189×10^8
Carbon, from Edison-Swan incandescent lamp	3834×10^8	3908×10^8	3955×10^8	4054×10^8
Carbon, adamantine, from Woodhouse and Rawson incandescent lamp	6168×10^8	6300×10^8	6363×10^8	6495×10^8

* "Phil. Mag." vol. 34, 1892.

† This is given by Dewar and Fleming as 13777 for 96°.4, which appears from the other measurements too high.

ALLOYS AT LOW TEMPERATURES.

by Cailletet and Bouty at very low temperatures. The results show that the coefficieot of change with temperature the alloys. The resistance of carboo was found by Dewar and Fleming to increase continuously to the lowest

ments or Müller, Benoit, and others. Probably the simplest rule is that suggested by Clausius, and showo by these temperature. This gives the actual change of resistance per degree, a constant; and heoce the percentage of chaoge approximately hold for alloys, some of which have a negative temperature coefficient at temperatures oot far from

Temperature =	— 100°	— 182°	— 197°	Mean value of temperature coefficient between — 100° and + 100° C.*
Metal or alloy.	Specific resistance io c. g. s. uoits.			
Aluminum, pure hard-drawn wire	1928	894	-	.00446
Copper, pure electrolytic and annealed . .	757	272	178	431
Gold, soft wire	1207	604	-	375
Iron, pure soft wire	4010	1067	608	578
Nickel, pure (prepared by Mond's process from compound of nickel and carbon monoxide) .	6110	1900	-	538
Platinum, annealed	5295	2821	2290	341
Silver, pure wire	962	472	-	377
Tin, pure wire	5671	2553	-	428
German silver, commercial wire . . .	33280	32512	-	035
Palladium-silver, 20 Pd + 80 Ag . . .	14256	13797	-	039
Phosphor-bronze, commercial wire . . .	7883	7371	-	070
Platinoid, Martino's platinoid with 1 to 2% tungsten .	42385	41454	-	025
Platinum-iridium, 80 Pt + 20 Ir . . .	26712	24440	-	087
Platinum-rhodium, 90 Pt + 10 Rh . . .	9834	7134	-	312
Platinum-silver, 66.7 Ag + 33.3 Pt . . .	26108	25537	-	024
Carbon, from Edison-Swan incandescent lamp .	4218×10⁸	4321×10⁸	-	-
Carbon, from Edison-Swan incandescent lamp .	4079×10⁸	4180×10⁸	-	031
Carbon, adamantine, from Woodhouse and Rawson incandescent lamp .	6533×10⁸	-	-	029

* This is a in the equation $R = R_0 (1 + at)$, as calculated from the equation $a = \frac{R_{100} - R_{-100}}{200 R_0}$.

TABLE 313. — Variation of Electrical Resistance of Glass and Porcelain with Temperature.

The following table gives the values of a, b, and c in the equation

$$\log R = a + bt + ct^2,$$

where R is the specific resistance expressed in ohms, that is, the resistance in ohms per centimeter of a rod one square centimeter in cross section.*

No.	Kind of glass.	Density.	a	b	c	Range of temp. Centigrade.
1	Test-tube glass	-	13.86	—.044	.000065	0°–250°
2	" " "	2.458	14.24	—.055	.0001	37–131
3	Bohemian glass	2.43	16.21	—.043	.0000394	60–174
4	Lime glass (Japanese manufacture)	2.55	13.14	—.031	—.000021	10–85
5	" " " "	2.499	14.002	—.025	—.00006	35–95
6	Soda-lime glass (French flask)	2.533	14.58	—.049	.000075	45–120
7	Potash-soda lime glass	2.58	16.34	—.0425	.0000364	66–193
8	Arsenic enamel flint glass	3.07	18.17	—.055	.000088	105–135
9	Flint glass (Thomson's electrometer jar)	3.172	18.021	—.036	—.0000091	100–200
10	Porcelain (white evaporating dish)	-	15.65	—.042	.00005	68–290

COMPOSITION OF SOME OF THE ABOVE SPECIMENS OF GLASS.

Number of specimen =	3	4	5	7	8	9
Silica	61.3	57.2	70.05	75.65	54.2	55.18
Potash	22.9	21.1	1.44	7.92	10.5	13.28
Soda	Lime, etc.	Lime, etc.	14.32	6.92	7.0	-
Lead oxide	by diff.	by diff.	2.70	-	23.9	31.01
Lime	15.8	16.7	10.33	8.48	0.3	0.35
Magnesia	-	-		0.36	0.2	0.06
Arsenic oxide	-	-	-		3.5	-
Alumina, iron oxide, etc.	-	-	1.45	0.70	0.4	0.67

* T. Gray, "Phil. Mag." 1880, and "Proc. Roy. Soc." 1882.

TABLE 314. — Temperature Resistance Coefficients of Glass, Porcelain and Quartz dr/dt.

Temperature.	450°	500°	575°	600°	700°	750°	800°	900°	1000°
Glass	—32.	—6.	—1.5	—.8	—0.17	—0.1	—0.06		-
Porcelain	-	-	—16.	—9.8	—2.8	—1.6	—.70	—0.30	—0.12
Quartz	-	-	-	-	-	—10.	—6.40	—2.60	—1.00

Somerville, Physical Review, 31, p. 261, 1910.

TABULAR COMPARISON OF WIRE GAGES.

Gage No.	American Wire Gage (B. & S.) Mils.	American Wire Gage (B. & S.) mm.	Steel Wire Gage* Mils.	Steel Wire Gage* mm.	Stubs' Steel Wire Gage Mils.	(British) Standard Wire Gage Mils.	Birmingham Wire Gage (Stubs') Mils.	Gage No.
7–0			490.0	12.4		500.		7–0
6–0			461.5	11.7		464.		6–0
5–0			430.5	10.9		432.		5–0
4–0	460.	11.7	393.8	10.0		400.	454.	4–0
3–0	410.	10.4	362.5	9.2		372.	425.	3–0
2–0	365.	9.3	331.0	8.4		348.	380.	2–0
0	325.	8.3	306.5	7.8		324.	340.	0
1	289.	7.3	283.0	7.2	227.	300.	300.	1
2	258.	6.5	262.5	6.7	219.	276.	284.	2
3	229.	5.8	243.7	6.2	212.	252.	259.	3
4	204.	5.2	225.3	5.7	207.	232.	238.	4
5	182.	4.6	207.0	5.3	204.	212.	220.	5
6	162.	4.1	192.0	4.9	201.	192.	203.	6
7	144.	3.7	177.0	4.5	199.	176.	180.	7
8	128.	3.3	162.0	4.1	197.	160.	165.	8
9	114.	2.91	148.3	3.77	194.	144.	148.	9
10	102.	2.59	135.0	3.43	191.	128.	134.	10
11	91.	2.30	120.5	3.06	188.	116.	120.	11
12	81.	2.05	105.5	2.68	185.	104.	109.	12
13	72.	1.83	91.5	2.32	182.	92.	95.	13
14	64.	1.63	80.0	2.03	180.	80.	83.	14
15	57.	1.45	72.0	1.83	178.	72.	72.	15
16	51.	1.29	62.5	1.59	175.	64.	65.	16
17	45.	1.15	54.0	1.37	172.	56.	58.	17
18	40.	1.02	47.5	1.21	168.	48.	49.	18
19	36.	0.91	41.0	1.04	164.	40.	42.	19
20	32.	.81	34.8	0.88	161.	36.	35.	20
21	28.5	.72	31.7	.81	157.	32.	32.	21
22	25.3	.62	28.6	.73	155.	28.	28.	22
23	22.6	.57	25.8	.66	153.	24.	25.	23
24	20.1	.51	23.0	.58	151.	22.	22.	24
25	17.9	.45	20.4	.52	148.	20.	20.	25
26	15.9	.40	18.1	.46	146.	18.	18.	26
27	14.2	.36	17.3	.439	143.	16.4	16.	27
28	12.6	.32	16.2	.411	139.	14.8	14.	28
29	11.3	.29	15.0	.381	134.	13.6	13.	29
30	10.0	.25	14.0	.356	127.	12.4	12.	30
31	8.9	.227	13.2	.335	120.	11.6	10.	31
32	8.0	.202	12.8	.325	115.	10.8	9.	32
33	7.1	.180	11.8	.300	112.	10.0	8.	33
34	6.3	.160	10.4	.264	110.	9.2	7.	34
35	5.6	.143	9.5	.241	108.	8.4	5.	35
36	5.0	.127	9.0	.229	106.	7.6	4.	36
37	4.5	.113	8.5	.216	103.	6.8		37
38	4.0	.101	8.0	.203	101.	6.0		38
39	3.5	.090	7.5	.191	99.	5.2		39
40	3.1	.080	7.0	.178	97.	4.8		40
41			6.6	.168	95.	4.4		41
42			6.2	.157	92.	4.0		42
43			6.0	.152	88.	3.6		43
44			5.8	.147	85.	3.2		44
45			5.5	.140	81.	2.8		45
46			5.2	.132	79.	2.4		46
47			5.0	.127	77.	2.0		47
48			4.8	.122	75.	1.6		48
49			4.6	.117	72.	1.2		49
50			4.4	.112	69.	1.0		50

* The Steel Wire Gage is the same gage which has been known by the various names: "Washburn and Moen," "Roebling," "American Steel and Wire Co.'s." Its abbreviation should be written "Stl. W. G.," to distinguish it from "S. W. G.," the usual abbreviation for the (British) Standard Wire Gage.

Taken from Circular No. 31. Copper Wire Tables, U.S. Bureau of Standards which contains more complete tables.

WIRE TABLES.

TABLE 316. — Introduction. Mass and Volume Resistivity of Copper and Aluminum.

The following wire tables are abridged from those prepared by the Bureau of Standards at the request and with the coöperation of the Standards Committee of the American Institute of Electrical Engineers (Circular No. 31 of the Bureau of Standards). The standard of copper resistance used is "The International Annealed Copper Standard" as adopted Sept. 5, 1913, by the International Electrotechnical Commission and takes the Resistivity at 20° C. of an annealed copper wire one meter long weighing one gram as equal to 0.15328 ohm. This standard corresponds to a conductivity of $58. \times 10^{-5}$ cgs. units, and a density of 8.89, at 20° C.

In the various units of mass and volume resistivity this may be stated as

0.15328 ohm (meter, gram) at 20° C.
875.20 ohms (mile, pound) at 20° C.
1.7241 microhm-cm. at 20° C.
0.67879 microhm-inch at 20° C.
10.371 ohms (mil, foot) at 20° C.

The temperature coefficient for this particular resistivity is $a_{20} = 0.00393$ or $a_0 = 0.00427$. However, the temperature coefficient is proportional to the conductivity, and hence the change of resistivity per degree C. is a constant, 0.000597 ohm (meter, gram). The "constant mass" temperature coefficient of any sample is

$$a_t = \frac{0.000597 + 0.000005}{\text{resistivity in ohms (meter, gram) at } t^\circ \text{ C}}.$$

The density is 8.89 grams per cubic centimeter at 20° C., which is equivalent to 0.3212 pounds per cubic inch.

The values in the tables are for annealed copper of standard resistivity. The user of the tables must apply the proper correction for copper of other resistivity. Hard-drawn copper may be taken as about 2.7 per cent higher resistivity than annealed copper.

The aluminum tables are based on a figure for the conductivity published by the U. S. Bureau of Standards, which is the result of many thousands of determinations by the Aluminum Company of America. A volume resistivity of 2.828 michrom-cm., and a density of 2.70 may be considered to be good average values for commercial hard-drawn aluminum. These values give:

Mass resistivity, in ohms (meter, gram) at 20° C.	0.0764
" " " " (mile, pound) at 20° C.	436.
Mass per cent conductivity	200.7%
Volume resistivity, in michrom-cm. at 20° C.	2.828
" " in microhm-inch at 20° C.	1.113
Volume per cent conductivity	61.0%
Density, in grams per cubic centimeter	2.70
Density, in pounds per cubic inch	0.0975

WIRE TABLES.

TABLE 317.—Temperature Coefficients of Copper for Different Initial Temperatures (Centigrade) and Different Conductivities.

Ohms (meter, gram) at 20° C.	Per cent conductivity.	a_0	a_{15}	a_{20}	a_{25}	a_{30}	a_{50}
0.161 34	95%	0.004 03	0.003 80	0.003 73	0.003 67	0.003 60	0.003 36
.159 66	96%	.004 08	.003 85	.003 77	.003 70	.003 64	.003 39
.158 02	97%	.004 13	.003 89	.003 81	.003 74	.003 67	.003 42
.157 53	97.3%	.004 14	.003 90	.003 82	.003 75	.003 68	.003 43
.156 40	98%	.004 17	.003 93	.003 85	.003 78	.003 71	.003 45
.154 82	99%	.004 22	.003 97	.003 89	.003 82	.003 74	.003 48
.153 28	100%	.004 27	.004 01	**.003 93**	.003 85	.003 78	.003 52
.151 76	101%	.004 31	.004 05	.00 397	.003 89	.003 82	.003 55

NOTE. — The fundamental relation between resistance and temperature is the following:

$$R_t = R_{t_1}(1 + a_{t_1}[t - t_1]),$$

where a_{t_1} is the "temperature coefficient," and t_1 is the "initial temperature" or "temperature of reference."

The values of a in the above table exhibit the fact that the temperature coefficient of copper is proportional to the conductivity. The table was calculated by means of the following formula, which holds for any per cent conductivity, n, within commercial ranges, and for centigrade temperatures. (n is considered to be expressed decimally: e.g., if per cent conductivity = 99 per cent, n = 0.99.)

$$a_{t_1} = \frac{1}{\frac{1}{n(0.00393)} + (t_1 - 20)}.$$

TABLE 318.—Reduction of Observations to Standard Temperature. (Copper.)

Temperature C.	Corrections to reduce Resistivity to 20° C. Ohm (meter, gram).	Microhm—cm.	Ohm (mile, pound).	Microhm—inch.	Factors to reduce Resistance to 20° C. For 96 per cent conductivity.	For 98 per cent conductivity.	For 100 per cent conductivity.	Temperature C.
0	+0.011 94	+0.1361	+ 68.20	+0.053 58	1.0816	1.0834	1.0853	0
5	+ .008 96	+ .1021	+ 51.15	+ .040 18	1.0600	1.0613	1.0626	5
10	+ .005 97	+ .0681	+ 34.10	.026 79	1.0392	1.0401	1.0409	10
11	+ .005 37	+ .0612	+ 30.69	' .024 11	1.0352	1.0359	1.0367	11
12	+ .004 78	+ .0544	+ 27.28	+ .021 43	1.0311	1.0318	1.0325	12
13	+ .004 18	+ .0476	+ 23.87	+ .018 75	1.0271	1.0277	1.0283	13
14	+ .003 58	+ .0408	+ 20.46	+ .016 07	1.0232	1.0237	1.0242	14
15	+ .002 99	+ .0340	+ 17.05	+ .013 40	1.0192	1.0196	1.0200	15
16	+ .002 39	+ .0272	+ 13.64	+ .010 72	1.0153	1.0156	1.0160	16
17	+ .001 79	+ .0204	+ 10.23	+ .008 04	1.0114	1.0117	1.0119	17
18	+ .001 19	+ .0136	+ 6.82	+ .005 36	1.0076	1.0078	1.0079	18
19	+ .000 60	+ .0068	+ 3.41	+ .002 68	1.0038	1.0039	1.0039	19
20	0	0	0	0	1.0000	1.0000	1.0000	20
21	− .000 60	− .0068	− 3.41	− .002 68	0.9962	0.9962	0.9961	21
22	− .001 19	− .0136	− 6.82	− .005 36	.9925	.9924	.9922	22
23	− .001 79	− .0204	− 10.23	− .008 04	.9888	.9886	.9883	23
24	− .002 39	− .0272	− 13.64	− .010 72	.9851	.9848	.9845	24
25	− .002 99	− .0340	− 17.05	− .013 40	.9815	.9811	.9807	25
26	− .003 58	− .0408	− 20.46	− .016 07	.9779	.9774	.9770	26
27	− .004 18	− .0476	− 23.87	− .018 75	.9743	.9737	.9732	27
28	− .004 78	− .0544	− 27.28	− .021 43	.9707	.9701	.9695	28
29	− .005 37	− .0612	− 30.69	− .024 11	.9672	.9665	.9658	29
30	− .005 97	− .0681	− 34.10	− .026 79	.9636	.9629	.9622	30
35	− .008 96	− .1021	− 51.15	− .040 18	.9464	.9454	.9443	35
40	− .011 94	− .1361	− 68.20	− .053 58	.9298	.9285	.9271	40
45	− .014 93	− .1701	− 85.25	− .066 98	.9138	.9122	.9105	45
50	− .017 92	− .2042	−102.30	− .080 37	.8983	.8964	.8945	50
55	− .020 90	− .2382	−119.35	− .093 76	.8833	.8812	.8791	55
60	− .023 89	− .2722	−136.40	− .107 16	.8689	.8665	.8642	60
65	− .026 87	− .3062	−153.45	− .120 56	.8549	.8523	.8497	65
70	− .029 86	− .3403	−170.50	− .133 95	.8413	.8385	.8358	70
75	− .032 85	− .3743	−187.55	− .147 34	.8281	.8252	.8223	75

WIRE TABLE, STANDARD ANNEALED COPPER.

American Wire Gage (B. & S.). English Units.

Gage No.	Diameter in Mils. at 20° C.	Cross-Section at 20° C.		Ohms per 1000 Feet.*			
		Circular Mils.	Square Inches.	0° C (=32° F)	20° C (=68° F)	50° C (=122° F)	75° C (=167° F)
0000	460.0	211 600.	0.1662	0.045 16	0.049 01	0.054 79	0.059 61
000	409.6	167 800.	.1318	.056 95	.061 80	.069 09	.075 16
00	364.8	133 100.	.1045	.071 81	.077 93	.087 12	.094 78
0	324.9	105 500.	.082 89	.090 55	.098 27	.1099	.1195
1	289.3	83 690.	.065 73	.1142	.1239	.1385	.1507
2	257.6	66 370.	.052 13	.1440	.1563	.1747	.1900
3	229.4	52 640.	.041 34	.1816	.1970	.2203	.2396
4	204.3	41 740.	.032 78	.2289	.2485	.2778	.3022
5	181.9	33 100.	.026 00	.2887	.3133	.3502	.3810
6	162.0	26 250.	.020 62	.3640	.3951	.4416	.4805
7	144.3	20 820.	.016 35	.4590	.4982	.5569	.6059
8	128.5	16 510.	.012 97	.5788	.6282	.7023	.7640
9	114.4	13 090.	.010 28	.7299	.7921	.8855	.9633
10	101.9	10 380.	.008 155	.9203	.9989	1.117	1.215
11	90.74	8234.	.006 467	1.161	1.260	1.408	1.532
12	80.81	6530.	.005 129	1.463	1.588	1.775	1.931
13	71.96	5178.	.004 067	1.845	2.003	2.239	2.436
14	64.08	4107.	.003 225	2.327	2.525	2.823	3.071
15	57.07	3257.	.002 558	2.934	3.184	3.560	3.873
16	50.82	2583.	.002 028	3.700	4.016	4.489	4.884
17	45.26	2048.	.001 609	4.666	5.064	5.660	6.158
18	40.30	1624.	.001 276	5.883	6.385	7.138	7.765
19	35.89	1288.	.001 012	7.418	8.051	9.001	9.792
20	31.96	1022.	.000 802 3	9.355	10.15	11.35	12.35
21	28.45	810.1	.000 636 3	11.80	12.80	14.31	15.57
22	25.35	642.4	.000 504 6	14.87	16.14	18.05	19.63
23	22.57	509.5	.000 400 2	18.76	20.36	22.76	24.76
24	20.10	404.0	.000 317 3	23.65	25.67	28.70	31.22
25	17.90	320.4	.000 251 7	29.82	32.37	36.18	39.36
26	15.94	254.1	.000 199 6	37.61	40.81	45.63	49.64
27	14.20	201.5	.000 158 3	47.42	51.47	57.53	62.59
28	12.64	159.8	.000 125 5	59.80	64.90	72.55	78.93
29	11.26	126.7	.000 099 53	75.40	81.83	91.48	99.52
30	10.03	100.5	.000 078 94	95.08	103.2	115.4	125.5
31	8.928	79.70	.000 062 60	119.9	130.1	145.5	158.2
32	7.950	63.21	.000 049 64	151.2	164.1	183.4	199.5
33	7.080	50.13	.000 039 37	190.6	206.9	231.3	251.6
34	6.305	39.75	.000 031 22	240.4	260.9	291.7	317.3
35	5.615	31.52	.000 024 76	303.1	329.0	367.8	400.1
36	5.000	25.00	.000 019 64	382.2	414.8	463.7	504.5
37	4.453	19.83	.000 015 57	482.0	523.1	584.8	636.2
38	3.965	15.72	.000 012 35	607.8	659.6	737.4	802.2
39	3.531	12.47	.000 009 793	766.4	831.8	929.8	1012.
40	3.145	9.888	.000 007 766	966.5	1049.	1173.	1276.

* Resistance at the stated temperatures of a wire whose length is 1000 feet at 20° C.

WIRE TABLE, STANDARD ANNEALED COPPER (continued).

American Wire Gage (B. & S.). English Units (continued).

Gage No.	Diameter in Mils. at 20° C.	Pounds per 1000 Feet.	Feet per Pound.	Feet per Ohm.* 0° C (=32° F)	20° C (=68° F)	50° C (=122° F)	75° C (=167° F)
0000	460.0	640.5	1.561	22 140.	20 400.	18 250.	16 780.
000	409.6	507.9	1.968	17 560.	16 180.	14 470.	13 300.
00	364.8	402.8	2.482	13 930.	12 830.	11 480.	10 550.
0	324.9	319.5	3.130	11 040.	10 180.	9103.	8367.
1	289.3	253.3	3.947	8758.	8070.	7219.	6636.
2	257.6	200.9	4.977	6946.	6400.	5725.	5262.
3	229.4	159.3	6.276	5508.	5075.	4540.	4173.
4	204.3	126.4	7.914	4368.	4025.	3600.	3309.
5	181.9	100.2	9.980	3464.	3192.	2855.	2625.
6	162.0	79.46	12.58	2747.	2531.	2264.	2081.
7	144.3	63.02	15.87	2179.	2007.	1796.	1651.
8	128.5	49.98	20.01	1728.	1592.	1424.	1309.
9	114.4	39.63	25.23	1370.	1262.	1129.	1038.
10	101.9	31.43	31.82	1087.	1001.	895.6	823.2
11	90.74	24.92	40.12	861.7	794.0	710.2	652.8
12	80.81	19.77	50.59	683.3	629.6	563.2	517.7
13	71.96	15.68	63.80	541.9	499.3	446.7	410.6
14	64.08	12.43	80.44	429.8	396.0	354.2	325.6
15	57.07	9.858	101.4	340.8	314.0	280.9	258.2
16	50.82	7.818	127.9	270.3	249.0	222.8	204.8
17	45.26	6.200	161.3	214.3	197.5	176.7	162.4
18	40.30	4.917	203.4	170.0	156.6	140.1	128.8
19	35.89	3.899	256.5	134.8	124.2	111.1	102.1
20	31.96	3.092	323.4	106.9	98.50	88.11	80.99
21	28.46	2.452	407.8	84.78	78.11	69.87	64.23
22	25.35	1.945	514.2	67.23	61.95	55.41	50.94
23	22.57	1.542	648.4	53.32	49.13	43.94	40.39
24	20.10	1.223	817.7	42.28	38.96	34.85	32.03
25	17.90	0.9699	1031.	33.53	30.90	27.64	25.40
26	15.94	.7692	1300.	26.59	24.50	21.92	20.15
27	14.20	.6100	1639.	21.09	19.43	17.38	15.98
28	12.64	.4837	2067.	16.72	15.41	13.78	12.67
29	11.26	.3836	2607.	13.26	12.22	10.93	10.05
30	10.03	.3042	3287.	10.52	9.691	8.669	7.968
31	8.928	.2413	4145.	8.341	7.685	6.875	6.319
32	7.950	.1913	5227.	6.614	6.095	5.452	5.011
33	7.080	.1517	6591.	5.245	4.833	4.323	3.974
34	6.305	.1203	8310.	4.160	3.833	3.429	3.152
35	5.615	.095 42	10 480.	3.299	3.040	2.719	2.499
36	5.000	.075 68	13 210.	2.616	2.411	2.156	1.982
37	4.453	.060 01	16 660.	2.075	1.912	1.710	1.572
38	3.965	.047 59	21 010.	1.645	1.516	1.356	1.247
39	3.531	.037 74	26 500.	1.305	1.202	1.075	0.9886
40	3.145	.029 93	33 410.	1.035	0.9534	0.8529	.7840

* Length at 20° C. of a wire whose resistance is 1 ohm at the stated temperatures.

WIRE TABLE, STANDARD ANNEALED COPPER (*continued*).

American Wire Gage (B. & S.). English Units (*continued*).

Gage No.	Diameter in Mils at 20° C.	Ohms per Pound. 0° C. (=32° F.)	Ohms per Pound. 20° C. (=68° F.)	Ohms per Pound. 50° C. (=122° F.)	Pounds per Ohm. 20° C. (=68° F.)
0000	460.0	0.000 070 51	0.000 076 52	0.000 085 54	13 070.
000	409.6	.000 1121	.000 1217	.000 1360	8219.
00	364.8	.000 1783	.000 1935	.000 2163	5169.
0	324.9	.000 2835	.000 3076	.000 3439	3251.
1	289.3	.000 4507	.000 4891	.000 5468	2044.
2	257.6	.000 7166	.000 7778	.000 8695	1286.
3	229.4	.001 140	.001 237	.001 383	808.6
4	204.3	.001 812	.001 966	.002 198	508.5
5	181.9	.002 881	.003 127	.003 495	319.8
6	162.0	.004 581	.004 972	.005 558	201.1
7	144.3	.007 284	.007 905	.008 838	126.5
8	128.5	.011 58	.012 57	.014 05	79.55
9	114.4	.018 42	.019 99	.022 34	50.03
10	101.9	.029 28	.031 78	.035 53	31.47
11	90.74	.046 56	.050 53	.056 49	19.79
12	80.81	.074 04	.080 35	.089 83	12.45
13	71.96	.1177	.1278	.1428	7.827
14	64.08	.1872	.2032	.2271	4.922
15	57.07	.2976	.3230	.3611	3.096
16	50.82	.4733	.5136	.5742	1.947
17	45.26	.7525	.8167	.9130	1.224
18	40.30	1.197	1.299	1.452	0.7700
19	35.89	1.903	2.065	2.308	.4843
20	31.96	3.025	3.283	3.670	.3046
21	28.46	4.810	5.221	5.836	.1915
22	25.35	7.649	8.301	9.280	.1205
23	22.57	12.16	13.20	14.76	.075 76
24	20.10	19.34	20.99	23.46	.047 65
25	17.90	30.75	33.37	37.31	.029 97
26	15.94	48.89	53.06	59.32	.018 85
27	14.20	77.74	84.37	94.32	.011 85
28	12.64	123.6	134.2	150.0	.007 454
29	11.26	196.6	213.3	238.5	.004 688
30	10.03	312.5	339.2	379.2	.002 948
31	8.928	497.0	539.3	602.9	.001 854
32	7.950	790.2	857.6	958.7	.001 166
33	7.080	1256.	1364.	1524.	.000 7333
34	6.305	1998.	2168.	2424.	.000 4612
35	5.615	3177.	3448.	3854.	.000 2901
36	5.000	5051.	5482.	6128.	.000 1824
37	4.453	8032.	8717.	9744.	.000 1147
38	3.965	12 770.	13 860.	15 490.	.000 072 15
39	3.531	20 310.	22 040.	24 640.	.000 045 38
40	3.145	32 290.	35 040.	39 170.	.000 028 54

WIRE TABLE, STANDARD ANNEALED COPPER.

American Wire Gage (B. & S.) Metric Units.

Gage No.	Diameter in mm. at 20° C.	Cross Section in mm.² at 20° C.	Ohms per Kilometer.*			
			0° C.	20° C.	50° C.	75° C.
0000	11.68	107.2	0.1482	0.1608	0.1798	0.1956
000	10.40	85.03	.1868	.2028	.2267	.2466
00	9.266	67.43	.2356	.2557	.2858	.3110
0	8.252	53.48	.2971	.3224	.3604	.3921
1	7.348	42.41	.3746	.4066	.4545	.4944
2	6.544	33.63	.4724	.5127	.5731	.6235
3	5.827	26.67	.5956	.6465	.7227	.7862
4	5.189	21.15	.7511	.8152	.9113	.9914
5	4.621	16.77	.9471	1.028	1.149	1.250
6	4.115	13.30	1.194	1.296	1.449	1.576
7	3.665	10.55	1.506	1.634	1.827	1.988
8	3.264	8.366	1.899	2.061	2.304	2.506
9	2.906	6.634	2.395	2.599	2.905	3.161
10	2.588	5.261	3.020	3.277	3.663	3.985
11	2.305	4.172	3.807	4.132	4.619	5.025
12	2.053	3.309	4.801	5.211	5.825	6.337
13	1.828	2.624	6.054	6.571	7.345	7.991
14	1.628	2.081	7.634	8.285	9.262	10.08
15	1.450	1.650	9.627	10.45	11.68	12.71
16	1.291	1.309	12.14	13.17	14.73	16.02
17	1.150	1.038	15.31	16.61	18.57	20.20
18	1.024	0.8231	19.30	20.95	23.42	25.48
19	0.9116	.6527	24.34	26.42	29.53	32.12
20	.8118	.5176	30.69	33.31	37.24	40.51
21	.7230	.4105	38.70	42.00	46.95	51.08
22	.6438	.3255	48.80	52.96	59.21	64.41
23	.5733	.2582	61.54	66.79	74.66	81.22
24	.5106	.2047	77.60	84.21	94.14	102.4
25	.4547	.1624	97.85	106.2	118.7	129.1
26	.4049	.1288	123.4	133.9	149.7	162.9
27	.3606	.1021	155.6	168.9	188.8	205.4
28	.3211	.080 98	196.2	212.9	238.0	258.9
29	.2859	.064 22	247.4	268.5	300.1	326.5
30	.2546	.050 93	311.9	338.6	378.5	411.7
31	.2268	.040 39	393.4	426.9	477.2	519.2
32	.2019	.032 03	496.0	538.3	601.8	654.7
33	.1798	.025 40	625.5	678.8	758.8	825.5
34	.1601	.020 14	788.7	856.0	956.9	1041.
35	.1426	.015 97	994.5	1079.	1207.	1313.
36	.1270	.012 67	1254.	1361.	1522.	1655.
37	.1131	.010 05	1581.	1716.	1919.	2087.
38	.1007	.007 967	1994.	2164.	2419.	2632.
39	.089 69	.006 318	2514.	2729.	3051.	3319.
40	.079 87	.005 010	3171.	3441.	3847.	4185.

*Resistance at the stated temperatures of a wire whose length is 1 kilometer at 20° C.

WIRE TABLE, STANDARD ANNEALED COPPER (*continued*).

American Wire Gage (B. & S.) Metric Units (*continued*).

Gage No.	Diameter in mm. at 20° C.	Kilograms per Kilometer.	Meters per Gram.	Meters per Ohm.* 0° C.	20° C.	50° C.	75° C.
0000	11.68	953.2	0.001 049	6749.	6219.	5563.	5113.
000	10.40	755.9	.001 323	5352.	4932.	4412.	4055.
00	9.266	599.5	.001 668	4245.	3911.	3499.	3216.
0	8.252	475.4	.002 103	3366.	3102.	2774.	2550.
1	7.348	377.0	.002 652	2669.	2460.	2200.	2022.
2	6.544	299.0	.003 345	2117.	1951.	1745.	1604.
3	5.827	237.1	.004 217	1679.	1547.	1384.	1272.
4	5.189	188.0	.005 318	1331.	1227.	1097.	1009.
5	4.621	149.1	.006 706	1056.	972.9	870.2	799.9
6	4.115	118.2	.008 457	837.3	771.5	690.1	634.4
7	3.665	93.78	.010 66	664.0	611.8	547.3	503.1
8	3.264	74.37	.013 45	526.6	485.2	434.0	399.0
9	2.906	58.98	.016 96	417.6	384.8	344.2	316.4
10	2.588	46.77	.021 38	331.2	305.1	273.0	250.9
11	2.305	37.09	.026 96	262.6	242.0	216.5	199.0
12	2.053	29.42	.034 00	208.3	191.9	171.7	157.8
13	1.828	23.33	.042 87	165.2	152.2	136.1	125.1
14	1.628	18.50	.054 06	131.0	120.7	108.0	99.24
15	1.450	14.67	.068 16	103.9	95.71	85.62	78.70
16	1.291	11.63	.085 95	82.38	75.90	67.90	62.41
17	1.150	9.226	.1084	65.33	60.20	53.85	49.50
18	1.024	7.317	.1367	51.81	47.74	42.70	39.25
19	0.9116	5.803	.1723	41.09	37.86	33.86	31.13
20	.8118	4.602	.2173	32.58	30.02	26.86	24.69
21	.7230	3.649	.2740	25.84	23.81	21.30	19.58
22	.6438	2.894	.3455	20.49	18.88	16.89	15.53
23	.5733	2.295	.4357	16.25	14.97	13.39	12.31
24	.5106	1.820	.5494	12.89	11.87	10.62	9.764
25	.4547	1.443	.6928	10.22	9.417	8.424	7.743
26	.4049	1.145	.8736	8.105	7.468	6.680	6.141
27	.3606	0.9078	1.102	6.428	5.922	5.298	4.870
28	.3211	.7199	1.389	5.097	4.697	4.201	3.862
29	.2859	.5709	1.752	4.042	3.725	3.332	3.063
30	.2546	.4527	2.209	3.206	2.954	2.642	2.429
31	.2268	.3590	2.785	2.542	2.342	2.095	1.926
32	.2019	.2847	3.512	2.016	1.858	1.662	1.527
33	.1798	.2258	4.429	1.599	1.473	1.318	1.211
34	.1601	.1791	5.584	1.268	1.168	1.045	0.9606
35	.1426	.1420	7.042	1.006	0.9265	0.8288	.7618
36	.1270	.1126	8.879	0.7974	.7347	.6572	.6041
37	.1131	.089 31	11.20	.6324	.5827	.5212	.4791
38	.1007	.070 83	14.12	.5015	.4621	.4133	.3799
39	.089 69	.056 17	17.80	.3977	.3664	.3278	.3013
40	.079 87	.044 54	22.45	.3154	.2906	.2600	.2390

* Length at 20° C. of a wire whose resistance is 1 ohm at the stated temperatures.

WIRE TABLE, STANDARD ANNEALED COPPER (*continued*).

American Wire Gage (B. & S.). Metric Units (*continued*).

Gage No.	Diameter in mm. at 20° C.	Ohms per Kilogram.			Grams per Ohm.
		0° C.	20° C.	50° C.	20° C.
0000	11.68	0.000 155 4	0.000 168 7	0.000 188 6	5 928 000.
000	10.40	.000 247 2	.000 268 2	.000 299 9	3 728 000.
00	9.266	.000 393 0	.000 426 5	.000 476 8	2 344 000.
0	8.252	.000 624 9	.000 678 2	.000 758 2	1 474 000.
1	7.348	.000 993 6	.001 078	.001 206	927 300.
2	6.544	.001 580	.001 715	.001 917	583 200.
3	5.827	.002 512	.002 726	.003 048	366 800.
4	5.189	.003 995	.004 335	.004 846	230 700.
5	4.621	.006 352	.006 893	.007 706	145 100.
6	4.115	.010 10	.010 96	.012 25	91 230.
7	3.665	.016 06	.017 43	.019 48	57 380.
8	3.264	.025 53	.027 71	.030 98	36 080.
9	2.906	.040 60	.044 06	.049 26	22 690.
10	2.588	.064 56	.070 07	.078 33	14 270.
11	2.305	.1026	.1114	.1245	8976.
12	2.053	.1632	.1771	.1980	5645.
13	1.828	.2595	.2817	.3149	3550.
14	1.628	.4127	.4479	.5007	2233.
15	1.450	.6562	.7122	.7961	1404.
16	1.291	1.043	1.132	1.266	883.1
17	1.150	1.659	1.801	2.013	555.4
18	1.024	2.638	2.863	3.201	349.3
19	0.9116	4.194	4.552	5.089	219.7
20	.8118	6.670	7.238	8.092	138.2
21	.7230	10.60	11.51	12.87	86.88
22	.6438	16.86	18.30	20.46	54.64
23	.5733	26.81	29.10	32.53	34.36
24	.5106	42.63	46.27	51.73	21.61
25	.4547	67.79	73.57	82.25	13.59
26	.4049	107.8	117.0	130.8	8.548
27	.3606	171.4	186.0	207.9	5.376
28	.3211	272.5	295.8	330.6	3.381
29	.2859	433.3	470.3	525.7	2.126
30	.2546	689.0	747.8	836.0	1.337
31	.2268	1096.	1189.	1329.	0.8410
32	.2019	1742.	1891.	2114.	.5289
33	.1798	2770.	3006.	3361.	.3326
34	.1601	4404.	4780.	5344.	.2092
35	.1426	7003.	7601.	8497.	.1316
36	.1270	11140.	12090.	13510.	.082 74
37	.1131	17710.	19220.	21480.	.052 04
38	.1007	28150.	30560.	34160.	.032 73
39	.089 69	44770.	48590.	54310.	.020 58
40	.079 87	71180.	77260.	86360.	.012 94

Hard-Drawn Aluminum Wire at 20° C. (or, 68° F.).

American Wire Gage (B. & S.). English Units.

Gage No.	Diameter in Mils.	Cross Section.		Ohms per 1000 Feet.	Pounds per 1000 Feet.	Pounds per Ohm.	Feet per Ohm.
		Circular Mils.	Square Inches.				
0000	460.	212 000.	0.166	0.0804	195.	2420.	12 400.
000	410.	168 000.	.132	.101	154.	1520.	9860.
00	365.	133 000.	.105	.128	122.	957.	7820.
0	325.	106 000.	.0829	.161	97.0	602.	6200.
1	289.	83 700.	.0657	.203	76.9	379.	4920.
2	258.	66 400.	.0521	.256	61.0	238.	3900.
3	229.	52 600.	.0413	.323	48.4	150.	3090.
4	204.	41 700.	.0328	.408	38.4	94.2	2450.
5	182.	33 100.	.0260	.514	30.4	59.2	1950.
6	162.	26 300.	.0206	.648	24.1	37.2	1540.
7	144.	20 800.	.0164	.817	19.1	23.4	1220.
8	128.	16 500.	.0130	1.03	15.2	14.7	970.
9	114.	13 100.	.0103	1.30	12.0	9.26	770.
10	102.	10 400.	.008 15	1.64	9.55	5.83	610.
11	91.	8230.	.006 47	2.07	7.57	3.66	484.
12	81.	6530.	.005 13	2.61	6.00	2.30	384.
13	72.	5180.	.004 07	3.29	4.76	1.45	304.
14	64.	4110.	.003 23	4.14	3.78	0.911	241.
15	57.	3260.	.002 56	5.22	2.99	.573	191.
16	51.	2580.	.002 03	6.59	2.37	.360	152.
17	45.	2050.	.001 61	8.31	1.88	.227	120.
18	40.	1620.	.001 28	10.5	1.49	.143	95.5
19	36.	1290.	.001 01	13.2	1.18	.0897	75.7
20	32.	1020.	.000 802	16.7	0.939	.0564	60.0
21	28.5	810.	.000 636	21.0	.745	.0355	47.6
22	25.3	642.	.000 505	26.5	.591	.0223	37.8
23	22.6	509.	.000 400	33.4	.468	.0140	29.9
24	20.1	404.	.000 317	42.1	.371	.008 82	23.7
25	17.9	320.	.000 252	53.1	.295	.005 55	18.8
26	15.9	254.	.000 200	67.0	.234	.003 49	14.9
27	14.2	202.	.000 158	84.4	.185	.002 19	11.8
28	12.6	160.	.000 126	106.	.147	.001 38	9.39
29	11.3	127.	.000 099 5	134.	.117	.000 868	7.45
30	10.0	101.	.000 078 9	169.	.0924	.000 546	5.91
31	8.9	79.7	.000 062 6	213.	.0733	.000 343	4.68
32	8.0	63.2	.000 049 6	269.	.0581	.000 216	3.72
33	7.1	50.1	.000 039 4	339.	.0461	.000 136	2.95
34	6.3	39.8	.000 031 2	428.	.0365	.000 085 4	2.34
35	5.6	31.5	.000 024 8	540.	.0290	.000 053 7	1.85
36	5.0	25.0	.000 019 6	681.	.0230	.000 033 8	1.47
37	4.5	19.8	.000 015 6	858.	.0182	.000 021 2	1.17
38	4.0	15.7	.000 012 3	1080.	.0145	.000 013 4	0.924
39	3.5	12.5	.000 009 79	1360.	.0115	.000 008 40	.733
40	3.1	9.9	.000 007 77	1720.	.0091	.000 005 28	.581

Hard-Drawn Aluminum Wire at 20° C.

American Wire Gage (B. & S.) Metric Units.

Gage No.	Diameter in mm.	Cross Section in mm.²	Ohms per Kilometer.	Kilograms per Kilometer.	Grams per Ohm.	Ohms per Meter.
0000	11.7	107.	0.264	289.	1 100 000.	3790.
000	10.4	85.0	.333	230.	690 000.	3010.
00	9.3	67.4	.419	182.	434 000.	2380.
0	8.3	53.5	.529	144.	273 000.	1890.
1	7.3	42.4	.667	114.	172 000.	1500.
2	6.5	33.6	.841	90.8	108 000.	1190.
3	5.8	26.7	1.06	72.0	67 900.	943.
4	5.2	21.2	1.34	57.1	42 700.	748.
5	4.6	16.8	1.69	45.3	26 900.	593.
6	4.1	13.3	2.13	35.9	16 900.	470.
7	3.7	10.5	2.68	28.5	10 600.	373.
8	3.3	8.37	3.38	22.6	6680.	296.
9	2.91	6.63	4.26	17.9	4200.	235.
10	2.59	5.26	5.38	14.2	2640.	186.
11	2.30	4.17	6.78	11.3	1660.	148.
12	2.05	3.31	8.55	8.93	1050.	117.
13	1.83	2.62	10.8	7.08	657.	92.8
14	1.63	2.08	13.6	5.62	413.	73.6
15	1.45	1.65	17.1	4.46	260.	58.4
16	1.29	1.31	21.6	3.53	164.	46.3
17	1.15	1.04	27.3	2.80	103.	36.7
18	1.02	0.823	34.4	2.22	64.7	29.1
19	0.91	.653	43.3	1.76	40.7	23.1
20	.81	.518	54.6	1.40	25.6	18.3
21	.72	.411	68.9	1.11	16.1	14.5
22	.64	.326	86.9	0.879	10.1	11.5
23	.57	.258	110.	.697	6.36	9.13
24	.51	.205	138.	.553	4.00	7.24
25	.45	.162	174.	.438	2.52	5.74
26	.40	.129	220.	.348	1.58	4.55
27	.36	.102	277.	.276	0.995	3.61
28	.32	.0810	349.	.219	.626	2.86
29	.29	.0642	440.	.173	.394	2.27
30	.25	.0509	555.	.138	.248	1.80
31	.227	.0404	700.	.109	.156	1.43
32	.202	.0320	883.	.0865	.0979	1.13
33	.180	.0254	1110.	.0686	.0616	0.899
34	.160	.0201	1400.	.0544	.0387	.712
35	.143	.0160	1770.	.0431	.0244	.565
36	.127	.0127	2230.	.0342	.0153	.448
37	.113	.0100	2820.	.0271	.009 63	.355
38	.101	.0080	3550.	.0215	.006 06	.282
39	.090	.0063	4480.	.0171	.003 81	.223
40	.080	.0050	5640.	.0135	.002 40	.177

DIELECTRIC STRENGTH.

TABLE 323. — Steady Potential Difference in Volts required to produce a Spark in Air with Ball Electrodes.

Spark length. cm.	*R* = 0. Points.	*R* = 0.25 cm.	*R* = 0.5 cm.	*R* = 1 cm.	*R* = 2 cm.	*R* = 3 cm.	*R* = ∞. Plates.
0.02	–	–	1560	1530			
0.04	–	–	2460	2430	2340		
0.06	–	–	3300	3240	3060		
0.08	–	–	4050	3990	3810		
0.1	3720	5010	4740	4560	4560	4500	4350
0.2	4680	8610	8490	8490	8370	7770	7590
0.3	5310	11140	11460	11340	11190	10560	10650
0.4	5970	14040	14310	14340	14250	13140	13560
0.5	6300	15990	16950	17220	16650	16470	16320
0.6	6840	17130	19740	20070	20070	19380	19110
0.8	8070	18960	23790	24780	25830	26220	24960
1.0	8670	20670	26190	27810	29850	32760	30840
1.5	9960	22770	29970	37260			
2.0	10140	24570	33060	45480			
3.0	11250	28380					
4.0	12210	29580					
5.0	13050						

Based on the results of Baille, Bichat-Blondot, Freyburg, Liebig, Macfarlane, Orgler, Paschen, Quincke, de la Rue, Wolff. For spark lengths from 1 to 200 wave-lengths of sodium light, see Earhart, Phys. Rev. 15, p. 163; Hobbs, Phil. Mag. 10, p. 607, 1905.

TABLE 324. — Alternating Current Potentials required to produce a Spark in Air with various Ball Electrodes.

The potentials given are the maxima of the alternating waves used. Frequency, 33 cycles per second.

Spark length. cm.	*R* = 1 cm.	*R* = 1.92	*R* = 5	*R* = 7.5	*R* = 10	*R* = 15
0.08	3770					
.10	4400	4380	4330	4290	4245	4230
.15	5990	5940	5830	5790	5800	5780
.20	7510	7440	7340	7250	7320	7330
.25	9045	8970	8850	8710	8760	8760
0.30	10480	10400	10270	10130	10180	10150
.35	11980	11890	11670	11570	11610	11590
.40	13360	13300	13100	12930	12980	12970
.45	14770	14700	14400	14290	14330	14320
.50	16140	16070	15890	15640	15690	15690
0.6	18700	18730	18550	18300	18350	18400
.7	21350	21380	21140	20980	20990	21000
.8	23820	24070	23740	23490	23540	23550
0.9	26190	26640	26400	26130	26110	26090
1.0	28380	29170	28950	28770	28680	28610
1.2	32400	34100	33790	33660	33640	33620
1.4	35850	38850	38850	38580	38620	38580
1.6	38750	43400	43570	43250	43520	
1.8	40900	–	48300	47900		
2.0	42950	–	–	52400		

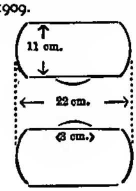
Based upon the results of Kawalski, Phil. Mag. 18, p. 699, 1909.

DIELECTRIC STRENGTH.

TABLE 325. — Potential Necessary to produce a Spark in Air between more widely Separated Electrodes.

Spark length, cm.	Dull points. Alternating current.	Steady potentials. Ball electrodes. R=1 cm.	Steady potentials. Ball electrodes. R=2.5 cm.	Steady potentials. Cup electrodes. Projection. 4.5 mm.	Steady potentials. Cup electrodes. Projection. 1.5 mm.	Spark length, cm.	Dull points. Alternating current.	Steady potentials. Ball electrodes. R=1 cm.	Steady potentials. Ball electrodes. R=2.5 cm.
0.3	-	-	-	-	11280	6.0	61000		86830
0.5	-	17610	17620	-	17420	7.0	-	52000	-
0.7	-	-	23050	-	22950	8.0	67000	52400	90200
1.0	12000	30240	31390	31400	31260	10.0	73000	74300	91930
1.2	-	33800	36810	-	36700	12.0	82600	-	93300
1.5	-	37930	44310	-	44510	14.0	92000	-	94400
2.0	29200	42320	56000	56500	56530	15.0	-	-	94700
2.5	-	45000	65180	-	68720	16.0	101000	-	101000
3.0	40000	46710	71200	80400	81140	20.0	119000		
3.5	-	-	75300	-	92400	25.0	140600		
4.0	48500	49100	78600	101700	103800	30.0	165700		
4.5	-	-	81540	-	114600	35.0	190900		
5.0	56500	50310	83800	-	126500				
5.5	-	-	-	-	135700				

This table for longer spark lengths contains the results of Voege, Ann. der Phys. 14, 1904, using alternating current and "dull point" electrodes, and the results with steady potential found in the recent very careful work of C. Müller, Ann. d. Phys. 28, p. 585, 1909.



The specially constructed electrodes for the columns headed "cup electrodes" had the form of a projecting knob 3 cm. in diameter and having a height of 4.5 mm. and 1.5 mm. respectively, attached to the plane face of the electrodes. These electrodes give a very satisfactory linear relation between the spark lengths and the voltage throughout the range studied.

TABLE 326. — Effect of the Pressure of the Gas on the Dielectric Strength.

Voltages are given for different spark lengths *l*.

Pressure. cm. Hg.	l=0.04	l=0.06	l=0.08	l=0.10	l=0.20	l=0.30	l=0.40	l=0.50
2	-	-	-	-	744	939	1110	1266
4	-	483	567	648	1015	1350	1645	1915
6	-	582	690	795	1290	1740	2140	2505
10	-	771	933	1090	1840	2450	3015	3580
15	-	1060	1280	1490	2460	3300	4080	4850
25	1110	1420	1725	2040	3500	4800	6000	7120
35	1375	1820	2220	2615	4505	6270	7870	9340
45	1640	2150	2660	3120	5475	7650	9620	11420
55	1820	2420	3025	3610	6375	8950	11290	13455
65	2040	2720	3400	4060	7245	10210	12950	15470
75	2255	3035	3805	4565	8200	11570	14650	17450

This table is based upon the results of Orgler, 1899. See this paper for work on other gases (or Landolt-Börnstein-Meyerhoffer).

For long spark lengths in various gases see Voege, Electrotechn. Z. 28, 1907. For dielectric strength of air and CO_2 in cylindrical air condensers, see Wien, Ann. d. Phys. 29, p. 679, 1909.

DIELECTRIC STRENGTH.

TABLE 327.—Dielectric Strength of Materials.

Potential necessary for puncture expressed in kilovolts per centimeter thickness of the dielectric.

Substance.	Kilovolts per cm	Substance.	Kilovolts per cm.	Substance.	Kilovolts per cm.
Ebonite	300–1100	Oils: Thickness		Papers:	
Empire cloth	80–300	Castor 0.2 mm.	190	Beeswaxed	770
" paper	450	" 1.0 "	130	Blotting	150
Fibre	20	Cottonseed	70	Manilla	25
Fuller board	200–300	Lard 0.2 "	140	Paraffined	500
Glass	300–1500	" 1.0 "	40	Varnished	100–250
Granite (fused)	90	Linseed, raw 0.2 "	185	Paraffine:	
Guttapercha	80–200	" " 1.0 "	90	Melted	75
Impregnated jute	20	" boiled 0.2 "	190	Melt point.	
Leatheroid	30–60	" " 1.0 "	80	Solid 43°	350
Linen, varnished	100–200	Lubricating	50	" 47°	400
Liquid air	40–90	Neatsfoot 0.2 "	200	" 52°	230
Mica: Thickness.		" 1.0 "	90	" 70°	450
Madras 0.1 mm.	1600	Olive 0.2 "	170	Presspaper	45–75
" 1.0 "	300	" 1.0 "	75	Rubber	160–500
Bengal 0.1 "	2200	Paraffin 0.2 "	215	Vaseline	90–130
" 1.0 "	700	" 1.0 "	160	Thickness.	
Canada 0.1 "	1500	Sperm, mineral 0.2 "	180	Xylol 0.2 mm.	140
" 1.0 "	500	" " 1.0 "	85	" 1.0 "	80
South America	1500	" natural 0.2 "	195		
Micanite	400	" " 1.0 "	90		
		Turpentine 0.2 "	160		
		" 1.0 "	110		

TABLE 328.—Potentials in Volts to Produce a Spark in Kerosene.

Spark length. mm.	Electrodes Balls of Diam. *d*.			
	0.5 cm.	1 cm.	2 cm.	3 cm.
0.1	3800	3400	2750	2200
.2	7500	6450	4800	3500
.3	10250	9450	7450	4600
.4	11750	10750	9100	5600
.5	13050	12400	11000	6900
.6	14000	13550	12250	8250
.8	15500	15100	13850	10450
1.0	16750	16400	15250	12350

Determinations of the dielectric strength of the same substance by different observers do not agree well. For a discussion of the sources of error see Mościcki, Electrotechn. *Z.* 25, 1904.

For more detailed information on the dependence of the sparking distance in oils as a function of the nature of the electrodes, see Edmondson, Phys. Review 6, p. 65, 1898.

TABLE 329. — Electrical Resistance of Straight Wires with Alternating Currents of Different Frequencies.

This table gives the ratio of the resistance of straight copper wires with alternating currents of different frequencies to the value of the resistance with direct currents.

Diameter of wire in millimeters.	Frequency n = 60	100	1000	10000	100000	1000000
0.05	–	–	–	–	–	*1.001
0.1	–	–	–	–	*1.001	1.008
0.25	–	–	–	–	1.003	1.247
0.5	–	–	–	*1.001	1.047	2.240
1.0	–	–	–	1.008	1.503	4.19
2	–	–	1.001	1.120	2.756	
3	–	–	1.006	1.437	4.00	
4	–	–	1.021	1.842		
5	–	*1.001	1.047	2.240		
7.5	1.001	1.002	1.210	3.22		
10	1.003	1.008	1.503	4.19		
15	1.016	1.038	2.136			
20	1.044	1.120	2.756			
25	1.105	1.247	3.38			
40	1.474	1.842				
100	3.31	4.19				

Values between 1.000 and 1.001 are indicated by *1.001.

The change of resistance of wires other than copper (iron wires excepted) may be calculated from the above table, making use of the fact that the change of resistance is a function of the argument $p = 2\pi r\sqrt{2n\lambda}$ where r = radius of cross-section, n = frequency, λ = conductivity.

If a given wire be wound into a solenoid, its resistance, at a given frequency, will be greater than the values in the table, which apply to straight wires only. The resistance in this case is a complicated function of the pitch and radius of the winding, the frequency, and the diameter of the wire, and is found by experiment to be sometimes as much as twice the value for a straight wire.

TABLE 330. — Electrical Resistance for High Frequencies.

For which the high frequency resistance will be less than 1 per cent greater than direct current resistance.

Wave-length.	Constantan or Advance Wire. Diameter.	Constantan or Advance Wire. Maximum Current.	Manganin Diameter.	Platinum Diameter.	Copper Diameter.
m.	*mm.*	*amp.*	*mm.*	*mm.*	*mm.*
100	0.30	3.5	0.29	0.13	0.006
200	0.46	4.5	0.40	0.29	0.045
300	0.57	5.5	0.50	0.27	0.09
400	0.66	7.0	0.60	0.30	0.10
600	0.83	8.0	0.75	0.37	0.15
800	0.98	10.0	0.88	0.42	0.20
1000	1.10	11.5	0.99	0.50	0.21
1200	1.20	12.5	1.10	0.57	0.22
1500	1.30	14.0	1.21	0.63	0.26
2000	1.52	17.0	1.38	0.73	0.30
3000	1.80	24.0	1.62	0.80	0.33

Advance wire is practically identical electrically with constantan, while for high resistance German silver the values are nearly the same as for manganin. The column of the table under maximum current gives the approximate current which may be carried by the various sizes without undue heating. The current capacity of the manganin is very nearly the same.

From Austin, Jour. Wash. Acad. of Sci. 2, p. 190, 1911.

TABLE 331.

WIRELESS TELEGRAPHY.

Wave-Length in Meters, Frequency in periods per second, and Oscillation Constant LC in Microhenries and Microfarads.

Meters.	n	L C	Meters.	n	L C	Meters.	n	L C
100	3,000,000	0.00282	600	500,000	0.101	1100	272,700	0.341
110	2,727,000	0.00341	610	491,800	0.105	1110	270,300	0.347
120	2,500,000	0.00405	620	485,500	0.108	1120	267,900	0.353
130	2,308,000	0.00476	630	476,200	0.111	1130	265,500	0.359
140	2,143,000	0.00552	640	468,700	0.115	1140	263,100	0.366
150	2,000,000	0.00633	650	461,500	0.119	1150	260,900	0.372
160	1,875,000	0.00721	660	454,500	0.123	1160	258,600	0.379
170	1,765,000	0.00813	670	447,800	0.126	1170	256,400	0.385
180	1,667,000	0.00912	680	441,200	0.130	1180	254,200	0.392
190	1,579,000	0.01016	690	434,800	0.134	1190	252,100	0.399
200	1,500,000	0.0113	700	428,600	0.138	1200	250,000	0.405
210	1,429,000	0.0124	710	422,500	0.142	1210	247,900	0.412
220	1,364,000	0.0136	720	416,700	0.146	1220	245,900	0.419
230	1,304,000	0.0149	730	411,000	0.150	1230	243,900	0.426
240	1,250,000	0.0162	740	405,400	0.154	1240	241,900	0.433
250	1,200,000	0.0176	750	400,000	0.158	1250	240,000	0.440
260	1,154,000	0.0190	760	394,700	0.163	1260	238,100	0.447
270	1,111,000	0.0205	770	389,600	0.167	1270	236,200	0.454
280	1,071,000	0.0221	780	384,600	0.171	1280	234,400	0.461
290	1,034,000	0.0237	790	379,800	0.176	1290	232,600	0.468
300	1,000,000	0.0253	800	375,000	0.180	1300	230,800	0.476
310	967,700	0.0270	810	370,400	0.185	1310	229,000	0.483
320	937,500	0.0288	820	365,900	0.189	1320	227,300	0.490
330	909,100	0.0307	830	361,400	0.194	1330	225,600	0.498
340	882,400	0.0326	840	357,100	0.199	1340	223,900	0.505
350	859,100	0.0345	850	352,900	0.203	1350	222,200	0.513
360	833,300	0.0365	860	348,800	0.208	1360	220,600	0.521
370	810,800	0.0385	870	344,800	0.213	1370	218,900	0.529
380	789,500	0.0406	880	340,900	0.218	1380	217,400	0.536
390	769,200	0.0428	890	337,100	0.223	1390	215,800	0.544
400	750,000	0.0450	900	333,300	0.228	1400	214,300	0.552
410	731,700	0.0473	910	329,700	0.233	1410	212,800	0.559
420	714,300	0.0496	920	326,100	0.238	1420	211,300	0.567
430	697,700	0.0520	930	322,600	0.243	1430	209,800	0.576
440	681,800	0.0545	940	319,100	0.249	1440	208,300	0.584
450	666,700	0.0570	950	315,900	0.254	1450	206,900	0.592
460	652,200	0.0596	960	312,500	0.259	1460	205,500	0.600
470	638,300	0.0622	970	309,300	0.265	1470	204,100	0.608
480	625,000	0.0649	980	306,100	0.270	1480	202,700	0.617
490	612,200	0.0676	990	303,000	0.276	1490	201,300	0.625
500	600,000	0.0704	1000	300,000	0.281	1500	200,000	0.633
510	588,200	0.0732	1010	297,000	0.287	1510	198,700	0.642
520	576,900	0.0761	1020	294,100	0.293	1520	197,400	0.650
530	566,000	0.0791	1030	291,300	0.299	1530	196,100	0.659
540	555,600	0.0821	1040	288,400	0.305	1540	194,800	0.668
550	545,500	0.0851	1050	285,700	0.310	1550	193,600	0.676
560	535,700	0.0883	1060	283,600	0.316	1560	192,300	0.685
570	526,300	0.0915	1070	280,400	0.322	1570	191,100	0.694
580	517,200	0.0947	1080	277,800	0.328	1580	189,900	0.703
590	508,500	0.0981	1090	275,200	0.335	1590	188,700	0.712

Prepared by Greenleaf W. Picard; copyright by Wireless Specialty Apparatus Company, New York. Computed on basis of 300,000 kilometers per second for the velocity of propagation of electromagnetic waves.

WIRELESS TELEGRAPHY.

Wave-Length, Frequency and Oscillation Constant.

Meters.	n	L C	Meters.	n	L C	Meters.	n	L C
1600	187,500	0.721	2000	150,000	1.13	6000	50,000	10.1
1610	186,300	0.730	2100	142,900	1.24	6100	49,180	10.5
1620	185,200	0.739	2200	136,400	1.36	6200	48,550	10.8
1630	184,100	0.748	2300	130,400	1.49	6300	47,620	11.1
1640	182,900	0.757	2400	125,000	1.62	6400	46,870	11.5
1650	181,800	0.766	2500	120,000	1.76	6500	46,150	11.9
1660	180,700	0.776	2600	115,400	1.90	6600	45,450	12.3
1670	179,600	0.785	2700	111,100	2.05	6700	44,780	12.6
1680	178,600	0.794	2800	107,100	2.21	6800	44,120	13.0
1690	177,500	0.804	2900	103,400	2.37	6900	43,480	13.4
1700	176,500	0.813	3000	100,000	2.53	7000	42,860	13.8
1710	175,400	0.823	3100	96,770	2.70	7100	42,250	14.2
1720	174,400	0.833	3200	93,750	2.88	7200	41,670	14.6
1730	173,400	0.842	3300	90,910	3.07	7300	41,100	15.0
1740	172,400	0.852	3400	88,240	3.26	7400	40,540	15.4
1750	171,400	0.862	3500	85,910	3.45	7500	40,000	15.8
1760	170,500	0.872	3600	83,330	3.65	7600	39,470	16.3
1770	169,400	0.882	3700	81,080	3.85	7700	38,960	16.7
1780	168,500	0.892	3800	78,950	4.06	7800	38,460	17.1
1790	167,600	0.902	3900	76,920	4.28	7900	37,980	17.6
1800	166,700	0.912	4000	75,000	4.50	8000	37,500	18.0
1810	165,700	0.923	4100	73,170	4.73	8100	37,040	18.5
1820	164,800	0.933	4200	71,430	4.96	8200	36,590	18.9
1830	163,900	0.943	4300	69,770	5.20	8300	36,140	19.4
1840	163,000	0.953	4400	68,180	5.45	8400	35,710	19.9
1850	162,200	0.963	4500	66,670	5.70	8500	35,290	20.3
1860	161,300	0.974	4600	65,220	5.96	8600	34,880	20.8
1870	160,400	0.985	4700	63,830	6.22	8700	34,480	21.3
1880	159,600	0.995	4800	62,500	6.49	8800	34,090	21.8
1890	158,700	1.006	4900	61,220	6.76	8900	33,710	22.3
1900	157,900	1.016	5000	60,000	7.04	9000	33,330	22.8
1910	157,100	1.026	5100	58,820	7.32	9100	32,970	23.3
1920	156,300	1.037	5200	57,690	7.61	9200	32,610	23.8
1930	155,400	1.048	5300	56,600	7.91	9300	32,260	24.3
1940	154,600	1.059	5400	55,560	8.21	9400	31,910	24.9
1950	153,800	1.070	5500	54,550	8.51	9500	31,590	25.4
1960	153,100	1.081	5600	53,570	8.83	9600	31,250	25.9
1970	152,300	1.092	5700	52,630	9.15	9700	30,930	26.5
1980	151,500	1.103	5800	51,720	9.47	9800	30,610	27.0
1990	150,800	1.114	5900	50,850	9.81	9900	30,310	27.6
						10000	30,000	28.1

TABLE 332.

WIRELESS TELEGRAPHY.

Radiation Resistances for Various Wave-Lengths and Antenna Heights.

The radiation theory of Hertz shows that the radiated energy of an oscillator may be represented by E = constant $(h^2/\lambda^2)\ I^2$, where h is the length of the oscillator, λ, the wave-length and I the current at its center. For a flat-top antenna $E = 1600\ (h^2/\lambda^2)\ I^2$ watts; $1600\ h^2/\lambda^2$ is called the radiation resistance.

(h = height to center of capacity of conducting system.)

h= / Wave-Length λ	40 Ft.	60 Ft.	80 Ft.	100 Ft.	120 Ft.	160 Ft.	200 Ft.	300 Ft.	450 Ft.	600 Ft.	1200 Ft.
m	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*	*ohm*
200	6.0	13.4	24.0	37.0	54.0	95.0					
300	2.7	6.0	10.6	16.5	23.8	42.4					
400	1.5	3.4	6.0	9.3	13.4	23.8					
600	0.66	1.5	2.7	4.1	6.0	10.6	16.4	37.4	84.0	149.0	
800	0.37	0.84	1.5	2.3	3.4	6.0	9.2	21.0	47.0	84.0	
1000	0.24	0.54	0.95	1.5	2.1	3.8	6.0	13.5	30.0	54.0	215.0
1200	0.17	0.37	0.66	1.03	1.5	2.6	4.1	9.3	21.0	37.0	149.0
1500	0.11	0.24	0.42	0.66	0.95	1.7	2.6	6.0	13.4	24.0	95.0
2000		0.13	0.24	0.37	0.54	0.95	1.5	3.4	7.5	13.4	54.0
2500			0.15	0.24	0.34	0.61	0.95	2.2	4.8	8.6	34.0
3000			0.11	0.17	0.24	0.42	0.66	1.5	3.4	6.0	24.0
4000			0.06	0.09	0.13	0.24	0.37	0.84	1.9	3.4	13.4
5000							0.24	0.53	1.20	2.2	8.6
6000							0.16	0.37	0.84	1.5	6.0
7000							0.12	0.27	0.61	1.1	4.4

Austin, Jour. Wash. Acad. of Sci. *1*, p. 190, 1911.

Table 333.

INTERNATIONAL ATOMIC WEIGHTS. ELECTROCHEMICAL EQUIVALENTS.

The International Atomic Weights are quoted from the report of the International Committee on Atomic Weights (Journal American Chemical Society, 35, p. 1807, 1913).

The Electrochemical equivalent of Silver is 0.0011180 gram. sec.$^{-1}$ amp.$^{-1}$. (See definition of International Ampere, p. xxxiii.) The electrochemical equivalent for any other element is

$$\frac{\text{atomic weight element}}{\text{atomic weight silver}} \times \frac{.0011180}{\text{valency}} \text{ gm. sec.}^{-1} \text{ amp.}^{-1}.$$

The equivalent for iodine has been recently (1913) determined at the Bureau of Standards as 1.3150. The valencies given are only those commonly shown by the elements.

Substance.	Symbol.	Relative atomic wt. Oxygen = 16.	Valency.	Substance.	Symbol.	Relative atomic wt. Oxygen = 16.	Valency.
Aluminum	Al	27.1	3.	Mercury	Hg	200.6	1, 2.
Antimony	Sb	120.2	3, 5.	Molybdenum	Mo	96.0	4, 6.
Argon	A	39.88	0.	Neodymium	Nd	144.3	3.
Arsenic	As	74.96	3, 5.	Neon	Ne	20.2	0.
Barium	Ba	137.37	2.	Nickel	Ni	58.68	2, 3.
Bismuth	Bi	208.0	3, 5.	Niton (Ra emanation)	Nt.	222.4	—
Boron	B	11.0	3.	Nitrogen	N	14.01	3, 5.
Bromine	Br	79.92	1.	Osmium	Os	190.9	6, 8.
Cadmium	Cd	112.40	2.	Oxygen	O	16.00	2.
Cæsium	Cs	132.81	1.	Palladium	Pd	106.7	2, 4.
Calcium	Ca	40.07	2.	Phosphorus	P	31.04	3, 5.
Carbon	C	12.00	4.	Platinum	Pt	195.2	2, 4.
Cerium	Ce	140.25	3, 4.	Potassium	K	39.10	1.
Chlorine	Cl	35.46	1.	Praseodymium	Pr	140.6	3.
Chromium	Cr	52.0	2, 3, 6.	Radium	Ra	226.4	2.
Cobalt	Co	58.97	2, 3.	Rhodium	Rh	102.9	3.
Columbium	Cb	93.5	5.	Rubidium	Rb	85.45	1.
Copper	Cu	63.57	1, 2.	Ruthenium	Ru	101.7	6, 8.
Dysprosium	Dy	162.5	3.	Samarium	Sa	150.4	3.
Erbium	Er	167.7	3.	Scandium	Sc	44.1	3.
Europium	Eu	152.0	3.	Selenium	Se	79.2	2, 4, 6.
Fluorine	F	19.0	1.	Silicon	Si	28.3	4.
Gadolinium	Gd	157.3	3.	Silver	Ag	107.88	1.
Gallium	Ga	69.9	3.	Sodium	Na	23.00	1.
Germanium	Ge	72.5	4.	Strontium	Sr	87.63	2.
Glucinum	Gl	9.1	2.	Sulphur	S	32.07	2, 4, 6.
Gold	Au	197.2	1, 3.	Tantalum	Ta	181.5	5.
Helium	He	3.99	0.	Tellurium	Te	127.5	2, 4, 6.
Holmium	Ho	163.5	3.	Terbium	Tb	159.2	3.
Hydrogen	H	1.008	1.	Thallium	Tl	204.0	1, 3.
				Thorium	Th	232.4	4.
Indium	In	114.8	3.	Thulium	Tm	168.5	3.
Iodine	I	126.92	1.	Tin	Sn	119.0	2, 4.
Iridium	Ir	193.1	4.	Titanium	Ti	48.1	4.
Iron	Fe	55.84	2, 3.	Tungsten	W	184.0	6.
Krypton	Kr	82.92	0.	Uranium	U	238.5	4, 6.
Lanthanum	La	139.0	3.	Vanadium	V	51.0	3, 5.
Lead	Pb	207.10	2, 4.	Xenon	Xe	130.2	0.
Lithium	Li	6.94	1.	Ytterbium	Yb	173.0	3.
Lutecium	Lu	174.0	3.	Yttrium	Yt	89.0	3.
Magnesium	Mg	24.32	2.	Zinc	Zn	65.37	2.
Manganese	Mn	54.93	2, 3, 7.	Zirconium	Zr	90.6	4.

CONDUCTIVITY OF ELECTROLYTIC SOLUTIONS.

This subject has occupied the attention of a considerable number of eminent workers in molecular physics, and a few results are here tabulated. It has seemed better to confine the examples to the work of one experimenter, and the tables are quoted from a paper by F. Kohlrausch,* who has been one of the most reliable and successful workers in this field.

The study of electrolytic conductivity, especially in the case of very dilute solutions, has furnished material for generalizations, which may to some extent help in the formation of a sound theory of the mechanism of such conduction. If the solutions are made such that per unit volume of the solvent medium there are contained amounts of the salt proportional to its electrochemical equivalent, some simple relations become apparent. The solutions used by Kohlrausch were therefore made by taking numbers of grams of the pure salts proportional to their electrochemical equivalent, and using a liter of water as the standard of quantity of the solvent. Taking the electrochemical equivalent number as the chemical equivalent or atomic weight divided by the valence, and using this number of grams to the liter of water, we get what is called the normal or gram molecule per liter solution. In the table, m is used to represent the number of gram molecules to the liter of water in the solution for which the conductivities are tabulated. The conductivities were obtained by measuring the resistance of a cell filled with the solution by means of a Wheatstone bridge alternating current and telephone arrangement. The results are for 18° C., and relative to mercury at 0° C., the cell having been standardized by filling with mercury and measuring the resistance. They are supposed to be accurate to within one per cent of the true value.

The tabular numbers were obtained from the measurements in the following manner: —

Let K_{18} = conductivity of the solution at 18° C. relative to mercury at 0° C.

K_{18}^{w} = conductivity of the solvent water at 18° C. relative to mercury at 0° C.

Then $K_{18} - K_{18}^{w} = k_{18}$ = conductivity of the electrolyte in the solution measured.

$\frac{k_{18}}{m} = \mu$ = conductivity of the electrolyte in the solution per molecule, or the "specific molecular conductivity."

TABLE 334. — Value of k_{18} for a few Electrolytes.

This short table illustrates the apparent law that the conductivity in very dilute solutions is proportional to the amount of salt dissolved.

m	KCl	$NaCl$	$AgNO_3$	$KC_2H_3O_2$	K_2SO_4	$MgSO_4$
0.000001	1.216	1.024	1.080	0.939	1.275	1.056
0.00002	2.434	2.056	2.146	1.886	2.532	2.104
0.00006	7.272	6.162	6.462	5.610	7.524	6.216
0.0001	12.09	10.29	10.78	9.34	12.49	10.34

TABLE 335. — Electro-Chemical Equivalents and Normal Solutions.

The following table of the electro-chemical equivalent numbers and the densities of approximately normal solutions of the salts quoted in Table 271 may be convenient. They represent grams per cubic centimeter of the solution at the temperature given.

Salt dissolved.	Grams per liter.	m	Temp. C.	Density.	Salt dissolved.	Grams per liter.	m	Temp. C.	Density.
KCl	74.59	1.0	15.2	1.0457	$\frac{1}{2}K_2SO_4$	87.16	1.0	18.9	1.0658
NH_4Cl	53.55	1.0009	18.6	1.0152	$\frac{1}{2}Na_2SO_4$	71.09	1.0003	18.6	1.0602
$NaCl$	58.50	1.0	18.4	1.0391	$\frac{1}{2}Li_2SO_4$	55.09	1.0007	18.6	1.0445
$LiCl$	42.48	1.0	18.4	1.0227	$\frac{1}{2}MgSO_4$	60.17	1.0023	18.6	1.0573
$\frac{1}{2}BaCl_2$	104.0	1.0	18.6	1.0888	$\frac{1}{2}ZnSO_4$	80.58	1.0	5.3	1.0794
$\frac{1}{2}ZnCl_2$	68.0	1.012	15.0	1.0592	$\frac{1}{2}CuSO_4$	79.9	1.001	18.2	1.0776
KI	165.9	1.0	18.6	1.1183	$\frac{1}{2}K_2CO_3$	69.17	1.0006	18.3	1.0576
KNO_3	101.17	1.0	18.6	1.0601	$\frac{1}{2}Na_2CO_3$	53.04	1.0	17.9	1.0517
$NaNO_3$	85.08	1.0	18.7	1.0542	KOH	56.27	1.0025	18.8	1.0477
$AgNO_3$	169.9	1.0	–	–	HCl	36.51	1.0041	18.6	1.0161
$\frac{1}{2}Ba(NO_3)_2$	65.28	0.5	–	–	HNO_3	63.13	1.0014	18.6	1.0318
$KClO_3$	61.29	0.5	18.3	1.0367	$\frac{1}{2}H_2SO_4$	49.06	1.0006	18.9	1.0300
$KC_2H_3O_2$	98.18	1.0005	18.6	1.0467					

* "Wied. Ann." vol. 26, pp. 161–226, 1885.

TABLE 336.

SPECIFIC MOLECULAR CONDUCTIVITY μ: MERCURY $=10^8$.

Salt dissolved.	$m=10$	5	3	1	0.5	0.1	.05	.03	.01
$\frac{1}{2}K_2SO_4$	–	–	–	–	672	736	897	959	1098
KCl	–	–	827	919	958	1047	1083	1107	1147
KI	–	770	900	968	997	1069	1102	1123	1161
NH_4Cl	–	752	825	907	948	1035	1078	1101	1142
KNO_3	–	–	572	752	839	983	1037	1067	1122
$\frac{1}{2}BaCl_2$	–	–	487	658	725	861	904	939	1006
$KClO_3$	–		–	–	799	927	(976)	1006	1053
$\frac{1}{2}Ba_2N_2O_6$		–	–	–	531	755	828	(870)	951
$\frac{1}{2}CuSO_4$	–		150	241	288	424	479	537	675
$AgNO_3$	–	351	448	635	728	886	936	(966)	1017
$\frac{1}{2}ZnSO_4$	–	82	146	249	302	431	500	556	685
$\frac{1}{2}MgSO_4$		82	151	270	330	474	532	587	715
$\frac{1}{2}Na_2SO_4$	–	–	–	475	559	734	784	828	906
$\frac{1}{2}ZnCl_2$	60	180	280	514	601	768	817	851	915
$NaCl$	–	398	528	695	757	865	897	(920)	962
$NaNO_3$	–	–	430	617	694	817	855	877	907
$KC_2H_3O_2$	30	240	381	594	671	784	820	841	879
$\frac{1}{2}Na_2CO_3$	–	–	254	427	510	682	751	799	899
$\frac{1}{2}H_2SO_4$	660	1270	1560	1820	1899	2084	2343	2515	2855
C_2H_4O	0.5	2.6	5.2	12	19	43	62	79	132
HCl	600	1420	2010	2780	3017	3244	3330	3369	3416
HNO_3	610	1470	2070	2770	2991	3225	3289	3328	3395
$\frac{1}{3}H_3PO_4$	148	160	170	200	250	430	540	620	790
KOH	423	990	1314	1718	1841	1986	2045	2078	2124
NH_3	0.5	2.4	3.3	8.4	12	31	43	50	92

Salt dissolved.	.006	.002	.001	.0006	.0002	.0001	.00006	.00002	.00001
$\frac{1}{2}K_2SO_4$	1130	1181	1207	1220	1241	1249	1254	1266	1275
KCl	1162	1185	1193	1199	1209	1209	1212	1217	1216
KI	1176	1197	1203	1209	1214	1216	1216	1216	1207
NH_4Cl	1157	1180	1190	1197	1204	1209	1215	1209	1205
KNO_3	1140	1173	1180	1190	1199	1207	1220	1198	1215
$\frac{1}{2}BaCl_2$	1031	1074	1092	1102	1118	1126	1133	1144	1142
$KClO_3$	1068	1091	1101	1109	1119	1122	1126	1135	1141
$\frac{1}{2}Ba_2N_2O_6$	982	1033	1054	1066	1084	1096	1100	1114	1114
$\frac{1}{2}CuSO_4$	740	873	950	987	1039	1062	1074	1084	1086
$AgNO_3$	1033	1057	1068	1069	1077	1078	1077	1073	1080
$\frac{1}{2}ZnSO_4$	744	861	919	953	1001	1023	1032	1047	1060
$\frac{1}{2}MgSO_4$	773	881	935	967	1015	1034	1036	1052	1056
$\frac{1}{2}Na_2SO_4$	933	980	998	1009	1026	1034	1038	1056	1054
$\frac{1}{2}ZnCl_2$	939	979	994	1004	1020	1029	1031	1035	1036
$NaCl$	976	998	1008	1014	1018	1029	1027	1028	1024
$NaNO_3$	921	942	952	956	966	975	970	972	975
$KC_2H_3O_2$	891	913	919	923	933	934	935	943	939
$\frac{1}{2}Na_2CO_3$	956	1010	1037	1046	988	874	790	715	697*
$\frac{1}{2}H_2SO_4$	3001	3240	3316	3342	3280	3118	2927	2077	1413*
C_2H_4O	170	283	380	470	796	995	1133	1328	1304*
HCl	3438	3455	3455	3440	3340	3170	2968	2057	1254*
HNO_3	3421	3448	3427	3408	3285	3088	2863	1904	1144*
$\frac{1}{3}H_3PO_4$	858	945	968	977	920	837	746	497	402*
KOH	2141	2140	2110	2074	1892	1689	1474	845	747*
NH_3	116	190	260	330	500	610	690	700	560*

* Acids and alkaline salts show peculiar irregularities.

LIMITING VALUES OF μ. TEMPERATURE COEFFICIENTS.

TABLE 337. — Limiting Values of μ.

This table shows limiting values of $\mu = \frac{k}{m} .10^8$ for infinite dilution for neutral salts, calculated from Table 271.

Salt.	μ	Salt.	μ	Salt.	μ	Salt.	μ
$\frac{1}{2}K_2SO_4$.	1280	$\frac{1}{2}BaCl_2$.	1150	$\frac{1}{2}MgSO_4$.	1080	$\frac{1}{2}H_2SO_4$.	3700
KCl . . .	1220	$\frac{1}{2}KClO_3$.	1150	$\frac{1}{2}Na_2SO_4$.	1060	HCl . .	3500
KI . . .	1220	$\frac{1}{2}BaN_2O_6$.	1120	$\frac{1}{2}ZnCl$ . .	1040	HNO_3 . .	3500
NH_4Cl . .	1210	$\frac{1}{2}CuSO_4$.	1100	NaCl . .	1030	$\frac{1}{3}H_3PO_4$.	1100
KNO_3 . .	1210	$AgNO_3$.	1090	$NaNO_3$.	980	KOH . .	2200
–	–	$\frac{1}{2}ZnSO_4$.	1080	$K_2C_2H_3O_2$	940	$\frac{1}{2}Na_2CO_3$.	1400

If the quantities in Table 336 be represented by curves, it appears that the values of the specific molecular conductivities tend toward a limiting value as the solution is made more and more dilute. Although these values are of the same order of magnitude, they are not equal, but depend on the nature of both the ions forming the electrolyte.

When the numbers in Table 337 are multiplied by Hittorf's constant, or 0.00011, quantities ranging between 0.14 and 0.10 are obtained which represent the velocities in millimetres per second of the ions when the electromotive force gradient is one volt per millimetre.

Specific molecular conductivities in general become less as the concentration is increased, which may be due to mutual interference. The decrease is not the same for different salts, but becomes much more rapid in salts of high valence.

Salts having acid or alkaline reactions show marked differences. They have small specific molecular conductivity in very dilute solutions, but as the concentration is increased the conductivity rises, reaches a maximum and again falls off. Kohlrausch does not believe that this can be explained by impurities. H_3PO_4 in dilute solution seems to approach a monobasic acid, while H_2SO_4 shows two maxima, and like H_3PO_4 approaches in very weak solution to a monobasic acid.

Kohlrausch concludes that the law of independent migration of the ions in media like water is sustained.

TABLE 338. — Temperature Coefficients.

The temperature coefficient in general diminishes with dilution, and for very dilute solutions appears to approach a common value. The following table gives the temperature coefficient for solutions containing 0.01 gram molecule of the salt.

Salt.	Temp. Coeff.	Salt.	Temp. Coeff.	Salt.	Temp. Coeff.	Salt.	Temp. Coeff.
KCl . . .	0.0221	KI . . .	0.0219	$\frac{1}{2}K_2SO_4$.	0.0223	$\frac{1}{2}K_2CO_3$ . .	0.0249
NH_4Cl . .	0.0226	KNO_3 . .	0.0216	$\frac{1}{2}Na_2SO_4$.	0.0240	$\frac{1}{2}Na_2CO_3$ . .	0.0265
NaCl . .	0.0238	$NaNO_3$ . .	0.0226	$\frac{1}{2}Li_2SO_4$.	0.0242	KOH . . .	0.0194
LiCl . . .	0.0232	$AgNO_3$ . .	0.0221	$\frac{1}{2}MgSO_4$.	0.0236	HCl . . .	0.0159
$\frac{1}{2}BaCl_2$ . .	0.0234	$\frac{1}{2}Ba(NO_3)_2$	0.0224	$\frac{1}{2}ZnSO_3$.	0.0234	HNO_3 . . .	0.0162
$\frac{1}{2}ZnCl_2$ . .	0.0239	$KClO_3$ . .	0.0219	$\frac{1}{2}CuSO_4$.	0.0229	$\frac{1}{2}H_2SO_4$ . .	0.0125
$\frac{1}{2}MgCl_2$.	0.0241	$KC_2H_3O_2$.	0.0229	–	–	$\frac{1}{2}H_2SO_4$ for $m = .001$	0.0159

THE EQUIVALENT CONDUCTIVITY OF SALTS, ACIDS AND BASES IN AQUEOUS SOLUTIONS.

In the following table the equivalent conductance is expressed in reciprocal ohms. The concentration is expressed in milli-equivalents of solute per litre of solution at the temperature to which the conductance refers. (In the cases of potassium hydrogen sulphate and phosphoric acid the concentration is expressed in milli-formula-weights of solute, $KHSO_4$ or H_3PO_4, per liter of solution, and the values are correspondingly the modal, or "formal," conductances.) Except in the cases of the strong acids the conductance of the water was subtracted, and for sodium acetate, ammonium acetate and ammonium chloride the values have been corrected for the hydrolysis of the salts. The atomic weights used were those of the International Commission for 1905, referred to oxygen as 16.00. Temperatures are on the hydrogen gas scale.

$$\text{Concentration in } \frac{\text{gram equivalents}}{\text{1000 liter}}.$$

$$\text{Equivalent conductance in } \frac{\text{reciprocal ohms per centimeter cube}}{\text{gram equivalents per cubic centimeter}}.$$

Substance.	Concentration.	Equivalent conductance at the following °C temperatures.									
		18°	25°	50°	75°	100°	128°	156°	218°	281°	306°
Potassium chloride .	0	130.1	(152.1)	(232.5)	(321.5)	414	(519)	625	825	1005	1120
" " .	2	126.3	146.4	–	–	393	–	588	779	930	1008
" " .	10	122.4	141.5	215.2	295.2	377	470	560	741	874	910
" " .	80	113.5	–	–	–	342	–	498	638	723	720
" " .	100	112.0	129.0	194.5	264.6	336	415	490			
Sodium chloride . .	0	109.0	–	–	–	362	–	555	760	970	1080
" " . .	2	105.6	–	–	–	349	–	534	722	895	955
" " . .	10	102.0	–	–	–	336	–	511	685	820	860
" " . .	80	93.5	–	–	–	301	–	450	500	674	680
" " . .	100	92.0	–	–	–	296	–	442			
Silver nitrate . . .	0	115.8	–	–	–	367	–	570	780	965	1065
" " . . .	2	112.2		–	–	353	–	539	727	877	935
" " . . .	10	108.0	–	–		337	–	507	673	790	818
" " . . .	20	105.1	–	–	–	326	–	488	639		
" " . . .	40	101.3	–	–	–	312	–	462	599	680	680
" " . . .	80	96.5	–	–	–	294	–	432	552	614	604
" " . . .	100	94.6	–	–	–	289					
Sodium acetate . .	0	78.1	–		–	285	–	450	660	–	924
" " . .	2	74.5	–	–	–	268	–	421	578	–	801
" " . .	10	71.2	–	–	–	253	–	396	542	–	702
" " . .	80	63.4	–	–	–	221	–	340	452		
Magnesium sulphate	0	114.1	–	–	–	426	–	690	1080		
" " .	2	94.3	–	–	–	302	–	377	260		
" " .	10	76.1	–	–	–	234	–	241	143		
" " .	20	67.5	–	–	–	190	–	195	110		
" " .	40	59.3	–	–	–	160	–	158	88		
" " .	80	52.0	–		–	136		133	75		
" " .	100	49.8	–	–	–	130	–	126			
" " .	200	43.1	–	–	–	110	–	109			
Ammonium chloride	0	131.1	152.0	–	–	(415)	–	(628)	(841)	–	(1176)
" " .	2	126.5	146.5	–	–	399	–	601	801	–	1031
" " .	10	122.5	141.7	–	–	382	–	573	758	–	925
" " .	30	118.1	–	–	–	–	–	–	–	–	828
Ammonium acetate .	0	(99.8)	–	–	–	(338)	–	(523)			
" " .	10	91.7	–	–	–	300	–	456			
" " .	25	88.2	–	–	–	286	–	426			

From the investigations of Noyes, Melcher, Cooper, Eastman and Kato; Journal of the American Chemical Society, 30, p. 335, 1908.

THE EQUIVALENT CONDUCTIVITY OF SALTS, ACIDS AND BASES IN AQUEOUS SOLUTIONS.

Substance.	Concentration.	Equivalent conductance at the following °C temperatures.									
		18°	25°	50°	75°	100°	128°	156°	218°	281°	306°
Barium nitrate . . .	0	116.9	–	–	–	385	–	600	840	1120	1300
" " . . .	2	109.7	–	–	–	352	–	536	715	828	824
" " . . .	10	101.0	–	–	–	322	–	481	618	658	615
" " . . .	40	88.7	–	–	–	280	–	412	507	503	448
" " . . .	80	81.6	–	–	–	258	–	372	449	430	
" " . . .	100	79.1	–	–	–	249					
Potassium sulphate .	0	132.8	–	–	–	455		715	1065	1460	1725
" " . .	2	124.8	–	–	–	402		605	806	893	867
" " . .	10	115.7	–	–	–	365	–	537	672	687	637
" " . .	40	104.2		–	–	320		455	545	519	466
" " . .	80	97.2	–	–	–	294		415	482	448	396
" " . .	100	95.0	–	–	–	286					
Hydrochloric acid .	0	379.0		–	–	850		1085	1265	1380	1424
" " . .	2	373.6	–	–	–	826	–	1048	1217	1332	1337
" " . .	10	368.1	–	–	–	807	–	1016	1168	1226	1162
" " . .	80	353.0	–	–	–	762	–	946	1044	1046	862
" " . .	100	350.6	–	–	–	754	–	929	1006		
Nitric acid	0	377.0	421.0	570	706	826	945	1047	(1230)	–	(1380)
" "	2	371.2	413.7	559	690	806	919	1012	1166	–	1156
" "	10	365.0	406.0	548	676	786	893	978			
" "	50	353.7	393.3	528	649	750	845	917			
" "	100	346.4	385.0	516	632	728	817	880	–	–	454*
Sulphuric acid . . .	0	383.0	(429)	(591)	(746)	891	(1041)	1176	1505	–	(2030)
" " . . .	2	353.9	390.8	501	561	571	551	536	563	–	637
" " . . .	10	309.0	337.0	406	435	446	460	481	533		
" " . . .	50	253.5	273.0	323	356	384	417	448	502		
" " . . .	100	233.3	251.2	300	336	369	404	435	483	–	474*
Potassium hydrogen sulphate . . .	2	455.3	506.0	661.0	754	784	773	754			
	50	295.5	318.3	374.4	403	422	446	477			
	100	263.7	283.1	329.1	354	375	402	435			
Phosphoric acid . .	0	338.3	376	510	631	730	839	930			
" " . .	2	283.1	311.9	401	464	498	508	489			
" " . .	10	203.0	222.0	273	300	308	298	274			
" " . .	50	122.7	132.6	157.8	168.6	168	158	142			
" " . .	100	96.5	104.0	122.7	129.9	128	120	108			
Acetic acid	0	(347.0)	–	–	–	(773)	–	(980)	(1165)	–	(1268)
" "	10	14.50	–		–	25.1	–	22.2	14.7		
" "	30	8.50	–	–	–	14.7	–	13.0	8.65		
" "	80	5.22	–	–	–	9.05	–	8.00	5.34		
" "	100	4.67	–	–	–	8.10	–	–	4.82	–	1.57
Sodium hydroxide .	0	216.5	–	–	–	594	–	835	1060		
" " . .	2	212.1	–		–	582	–	814			
" " . .	20	205.8	–	–	–	559	–	771	930		
" " . .	50	200.6	–	–	–	540	–	738	873		
Barium hydroxide .	0	222	256	389	(520)	645	(760)	847			
" " . . .	2	215	–	359	4	591					
" " . . .	10	207	235	342	449	548	664	722			
" " . . .	50	191.1	215.1	308	399	478	549	593			
" " . . .	100	180.1	204.2	291	373	443	503	531			
Ammonium hydroxide	0	(238)	(271)	(404)	(526)	(647)	(764)	(908)	(1141)	–	(1406)
	10	9.66	–	–	–	23.2	–	22.3	15.6		
	30	5.66	–	–	–	13.6	–	13.0			
	100	3.10	3.62	5.35	6.70	7.47	–	7.17	4.82	–	1.33

* These valnes are at the concentration 80.0.

TABLE 340.

THE EQUIVALENT CONDUCTIVITY OF SOME ADDITIONAL SALTS IN AQUEOUS SOLUTION.

Conditions similar to those of the preceding table except that the atomic weights for 1908 were used.

Substance.	Concentration.	Equivalent conductance at the following ° C temperature.							
		0°	18°	25°	50°	75°	100°	128°	156°
Potassium nitrate . . .	0	80.8	126.3	145.1	219	299	384	485	580
" " . . .	2	78.6	122.5	140.7	212.7	289.9	370.3	460.7	551
" " . . .	12.5	75.3	117.2	134.9	202.9	276.4	351.5	435.4	520.4
" " . . .	50	70.7	109.7	126.3	189.5	257.4	326.1	402.9	476.1
" " . . .	100	67.2	104.5	120.3	180.2	244.1	308.5	379.5	447.3
Potassium oxalate . . .	0	79.4	127.6	147.5	230	322	419	538	653
" " . . .	2	74.9	119.9	139.2	215.9	300.2	389.3	489.1	587
" " . . .	12.5	69.3	111.1	129.2	199.1	275.1	354.1	438.8	524.3
" " . . .	50	63	101	116.5	178.6	244.9	312.2	383.8	449.5
" " . . .	100	59.3	94.6	109.5	167	227.5	288.9	353.2	409.7
" " . . .	200	55.8	88.4	102.3	155	210.9	265.1	321.9	372.1
Calcium nitrate . . .	0	70.4	112.7	130.6	202	282	369	474	575
" " . . .	2	66.5	107.1	123.7	191.9	266.7	346.5	438.4	529.8
" " . . .	12.5	61.6	98.6	114.5	176.2	244	314.6	394.5	473.7
" " . . .	50	55.6	88.6	102.6	157.2	216.2	276.8	343	405.1
" " . . .	100	51.9	82.6	95.8	146.1	199.9	255.5	315.1	369.1
" " . . .	200	48.3	76.7	88.8	135.4	184.7	234.4	288	334.7
Potassium ferrocyanide .	0	98.4	159.6	185.5	288	403	527		
" " .	0.5	91.6	–	171.1					
" " .	2.	84.8	137	158.9	243.8	335.2	427.6		
" " .	12.5	71	113.4	131.6	200.3	271	340		
" " .	50	58.2	93.7	108.6	163.3	219.5	272.4		
" " .	100	53	84.9	98.4	148.1	198.1	245		
" " .	200	48.8	77.8	90.1	135.7	180.6	222.3		
" " .	400	45.4	72.1	83.3	124.8	165.7	203.1		
Barium ferrocyanide . .	0	91	150	176	277	393	521		
" " . .	2	46.9	75	86.2	127.5	166.2	202.3		
" " . .	12.5	30.4	48.8	56.5	83.1	107	129.8		
Calcium ferrocyanide .	0	88	146	171	271	386	512		
" " . .	2	47.1	75.5	86.2	130				
" " . .	12.5	31.2	49.9	57.4					
" " . .	50	24.1	38.5	44.4	64.6	81.9			
" " . .	100	21.9	35.1	40.2	58.4	73.7	84.3		
" " . .	200	20.6	32.9	37.8	55	68.7	77.5		
" " . .	400	20.2	32.2	37.1	54	67.5	76.2		
Potassium citrate . . .	0	76.4	124.6	144.5	228	320	420		
" " . . .	0.5	–	120.1	139.4					
" " . . .	2	71	115.4	134.5	210.1	293.8	381.2		
" " . . .	5	67.6	109.9	128.2	198.7	276.5	357.2		
" " . . .	12.5	62.9	101.8	118.7	183.6	254.2	326		
" " . . .	50	54.4	87.8	102.1	157.5	215.5	273		
" " . . .	100	50.2	80.8	93.9	143.7	196.5	247.5		
" " . . .	300	43.5	69.8	81	123.5	167	209.5		
Lanthanum nitrate . .	0	75.4	122.7	142.6	223	313	413	534	651
" " . .	2	68.9	110.8	128.9	200.5	279.8	363.5	457.5	549
" " . .	12.5	61.4	98.5	114.4	176.7	243.4	311.2	383.4	447.8
" " . .	50	54	86.1	99.7	152.5	207.6	261.4	315.8	357.7
" " . .	100	49.9	79.4	91.8	139.5	189.1	236.7	282.5	316.3
" " . .	200	46	72.1	83.5	126.4	170.2	210.8	249.6	276.2

From the investigations of Noyes and Johnston, Journal of the American Chemical Society, 31, p. 287, 1909.

CONDUCTANCE OF IONS. — HYDROLYSIS OF AMMONIUM ACETATE.

TABLE 341. — The Equivalent Conductance of the Separate Ions.

Ion.	0°	18°	25°	50°	75°	100°	128°	156°
K	40.4	64.6	74.5	115	159	206	263	317
Na	26	43.5	50.9	82	116	155	203	249
NH_4	40.2	64.5	74.5	115	159	207	264	319
Ag	32.9	54.3	63.5	101	143	188	245	299
$\frac{1}{2}Ba$	33	55[2]	65	104	149	200	262	322
$\frac{1}{2}Ca$	30	51[2]	60	98	142	191	252	312
$\frac{1}{3}La$	35	61	72	119	173	235	312	388
Cl	41.1	65.5	75.5	116	160	207	264	318
NO_3	40.4	61.7	70.6	104	140	178	222	263
$C_2H_3O_2$	20.3	34.6	40.8	67	96	130	171	211
$\frac{1}{2}SO_4$	41	68[2]	79	125	177	234	303	370
$\frac{1}{2}C_2O_4$	39	63[2]	73	115	163	213	275	336
$\frac{1}{3}C_6H_5O_7$	36	60	70	113	161	214		
$\frac{1}{4}Fe(CN)_6$	58	95	111	173	244	321		
H	240	314	350	465	565	644	722	777
OH	105	172	192	284	360	439	525	592

From Johnson, Journ. Amer. Chem. Soc., 31, p. 1010, 1909.

TABLE 342. — Hydrolysis of Ammonium Acetate and Ionization of Water.

Temperature.	Percentage hydrolysis.	Ionization constant of water.	Hydrogen-ion concentration in pure water. Equivalents per liter.
t	$100h$	$K_W \times 10^{14}$	$C_H \times 10^7$
0	-	0.089	0.30
18	(0.35)	0.46	0.68
25	-	0.82	0.91
100	4.8	48.	6.9
156	18.6	223.	14.9
218	52.7	461.	21.5
306	91.5	168.	13.0

Noyes, Kato, Kanolt, Sosman, No. 63 Publ. Carnegie Inst., Washington.

DIELECTRIC CONSTANTS.

TABLE 343. — Dielectric Constant (Specific Inductive Capacity) of Gases. Atmospheric Pressure.

Wave-lengths of the measuring current greater than 10000 cm.

Gas.	Temp. °C.	Dielectric constant referred to		Authority.
		Vacuum=1	Air=1	
Air	0	1.000590	1.000000	Boltzmann, 1875.
"	–	1.000586	1.000000	Klemenčič, 1885.
Ammonia	20	1.00718	1.00659	Bädeker, 1901.
Carbon bisulphide	0	1.00290	1.00231	Klemenčič.
" "	100	1.00239	1.00180	Bädeker.
Carbon dioxide	0	1.000946	1.000356	Boltzmann.
" "	0	1.000985	1.000399	Klemenčič.
Carbon monoxide	0	1.000690	1.000100	Boltzmann.
" "	0	1.000695	1.000109	Klemenčič.
Ethylene	0	1.00131	1.00072	Boltzmann.
"	0	1.00146	1.00087	Klemenčič.
Hydrochloric acid	100	1.00258	1.00199	Bädeker.
Hydrogen	0	1.000264	0.999674	Boltzmann.
"	0	1.000264	0.999678	Klemenčič.
Methane	0	1.000944	1.000354	Boltzmann.
"	0	1.000953	1.000367	Klemenčič.
Nitrous oxide (N_2O)	0	1.00116	1.00057	Boltzmann.
" " "	0	1.00099	1.00041	Klemenčič.
Sulphur dioxide	0	1.00993	1.00934	Bädeker.
" "	0	1.00905	1.00846	Klemenčič.
Water vapor, 4 atmospheres	145	1.00705	1.00646	Bädeker.

TABLE 344. — Variation of the Dielectric Constant with the Temperature.

For variation with the pressure see next table.

If D_θ = the dielectric constant at the temperature θ° C., D_t at the temperature t° C., and α and β are quantities given in the following table, then

$$D_\theta = D_t[1 - \alpha(t-\theta) + \beta(t-\theta)^2].$$

The temperature coefficients are due to Bädeker.

Gas.	α	β	Range of temp. °C.
Ammonia	5.45×10^{-5}	2.59×10^{-7}	10 — 110
Sulphur dioxide	6.19×10^{-5}	1.86×10^{-7}	0 — 110
Water vapor	1.4×10^{-4}	–	145

The dielectric constant of air at atmospheric pressure but with varying temperature may also be calculated from the fact that $D - 1$ is approximately proportional to the density.

DIELECTRIC CONSTANTS (*continued*).

TABLE 345.—Change of the Dielectric Constant of Gases with the Pressure.

Gas.	Temperature, ° C.	Pressure atmos.	Dielectric constant.	Authority.
Air	19	20	1.0108	Tangl, 1907.
"	–	40	1.0218	" "
"	–	60	1.0330	" "
"	–	80	1.0439	" "
"	–	100	1.0548	" "
"	11	20	1.0101	Occhialini, 1905.
"	–	40	1.0196	" "
"	–	60	1.0294	" "
"	–	80	1.0387	" "
"	–	100	1.0482	" "
"	–	120	1.0579	" "
"	–	140	1.0674	" "
"	–	160	1.0760	" "
"	–	180	1.0845	" "
Carbon dioxide . .	15	10	1.008	Linde, 1895.
" " . .	–	20	1.020	" "
" " . .	–	40	1.060	" "
Nitrous oxide, N_2O	15	10	1.010	"
" " "	–	20	1.025	"
" " "	–	40	1.070	"

TABLE 346.—Dielectric Constants of Liquids.

A wave-length greater than 10000 centimeters is denoted by ∞.

Substance.	Temp. ° C.	Wave-length, cm.	Dielectric constant.	Authority.	Substance.	Temp. ° C.	Wave-length, cm.	Dielectric constant.	Authority.
Alcohol:					Alcohol:				
Amyl . . .	frozen	∞	2.4	1	Methyl . .	−50	∞	45.3	1
" . . .	−100	"	30.1	1	" . . .	0	"	35.0	1
" . . .	−50	"	23.0	1	" . . .	+20	"	31.2	1
" . . .	0	"	17.4	1	" . . .	17	75	33.2	2
" . . .	+20	"	16.0	1	Propyl . .	−120	∞	46.2	1
" . . .	18	200	10.8	2	" . . .	−60	"	33.7	1
" . . .	18	73	4.7	2	" . . .	0	"	24.8	1
Ethyl . . .	frozen	∞	2.7	1	" . . .	+20	"	22.2	1
" . . .	−120	"	54.6	1	" . . .	15	75	12.3	2
" . . .	−80	"	44.3	1	Acetone . . .	−80	∞	33.8	5
" . . .	−40	"	35.3	1	" . . .	0	"	26.6	5
" . . .	0	"	28.4	1	" . . .	15	1200	21.85	6
" . . .	+20	"	25.8	1	" . . .	17	73	20.7	7
" . . .	17	200	24.4	2	Acetic acid .	18	∞	9.7	8
" . . .	"	75	23.0	2	" " . .	15	1200	10.3	6
" . . .	"	53	20.6	3	" " . .	17	200	7.07	2
" . . .	"	4	8.8	3	" " . .	19	75	6.29	2
" . . .	"	0.4	5.0	4	Amyl acetate .	19	∞	4.81	9
Methyl . .	frozen	∞	3.07	1	Amylene . .	16	"	2.20	10
" . . .	−100	"	58.0	1					

References on page 311.

DIELECTRIC CONSTANTS OF LIQUIDS.

A wave-length greater than 10000 centimeters is desiguated by ∞.

Substance.	Temp. °C.	Wave-length cm.	Diel. const.	Authority.
Anilin	18	∞	7.316	11
Benzol (benzene) .	18	"	2.288	"
" " .	19	73	2.26	2
Bromine	23	84	3.18	12
Carbon bisulphide	20	∞	2.626	13
" " .	17	73	2.64	2
Chloroform . . .	18	∞	5.2	11
" . . .	17	73	4.95	2
Decane	14	∞	1.97	10
Decylene . . .	17	"	2.24	"
Ethyl ether . .	−80	∞	7.05	5
" " . . .	−40	"	5.67	"
" " . . .	0	"	4.68	"
" " . . .	18	"	4.368	11
" " . . .	20	"	4.30	13
" " . . .	60	"	3.65	"
" " . . .	100	"	3.12	"
" " . . .	140	"	2.66	"
" " . . .	180	"	2.12	"
" " . . .	Crit. temp. 192	"	1.53	"
" " . . .	18	83	4.35	14
Formic acid . .	+2	73	19.0	2
" " . . .	(frozen) 15	1200	62.0	6
" " . . .	16	73	58.5	2
Glycerine . . .	15	1200	56.2	6
"	15	200	39.1	2
"	15	75	25.4	"
"	–	8.5	4.4	15
"	–	0.4	2.6	4
Hexane	17	∞	1.880	16
Hydrogen peroxide 46% in H_2O	18	75	84.7	17

Substance.	Temp. °C.	Wave-length cm.	Diel. const.	Authority.
Nitrobenzol . . .	(frozen) −10	∞	9.9	1
" . . .	−5	"	42.0	"
" . . .	0	"	41.0	"
" . . .	+15	"	37.8	"
" . . .	30	"	35.1	"
" . . .	18	"	36.45	11
" . . .	17	73	34.0	2
Octane	17	∞	1.949	16
Oils:				
Almond . . .	20	∞	2.83	18
Castor	11	"	4.67	19
Colza	20	"	3.11	20
Cottonseed . .	14	"	3.10	21
Lemon	21	"	2.25	22
Linseed . . .	13	"	3.35	21
Neatsfoot . . .	–	"	3.02	20
Olive	20	"	3.11	23
Peanut	11.4	"	3.03	21
Petroleum . .		2000	2.13	24
Petroleum ether	20	∞	1.92	20
Rape seed . .	16	"	2.85	21
Sesame . . .	13.4	"	3.02	"
Sperm	20	"	3.17	20
Turpentine . .	20	"	2.23	"
Vaseline . . .	–	"	2.17	25
Phenol	48	73	9.68	2
Toluol	−83	∞	2.51	5
"	+16	"	2.33	"
"	19	73	2.31	2
Meta-xylol . . .	18	∞	2.376	11
" " . . .	17	73	2.37	2
Water	18	∞	81.07	11
for temp. coeff.	17	200	80.6	2
see Table 344.	17	74	81.7	"
	17	38	83.6	"

1 Abegg-Seitz, 1899.
2 Drude, 1896.
3 Marx, 1898.
4 Lampa, 1896.
5 Abegg, 1897.
6 Thwing, 1894.
7 Drude, 1898.
8 Francke, 1893.
9 Löwe, 1898.
10 Landolt-Jahn, 1892.
11 Turner, 1900.
12 Schlundt.
13 Tangl, 1903.
14 Coolidge, 1899.
15 v. Lang, 1896.
16 Nernst, 1894.
17 Calvert, 1900.
18 Hasenöhrl, 1896.
19 Arons-Rubens, 1892.
20 Hopkinson, 1881.
21 Salvioni, 1888.
22 Tomaszewski, 1888.
23 Heinke, 1896.
24 Marx.
25 Fuchs.

DIELECTRIC CONSTANTS OF LIQUIDS (*continued*).

TABLE 347.—Temperature Coefficients of the Formula:

$$D_\theta = D_t[1 - \alpha(t-\theta) + \beta(t-\theta)^2].$$

Substance.	α	β	Temp. range, °C.	Authority.
Amyl acetate	0.0024	–	–	Löwe.
Aniline	0.00351	–	–	Ratz.
Benzol	0.00106	0.0000087	10–40	Hasenöhrl.
Carbon bisulphide	0.000966	–	–	Ratz.
" "	0.000922	0.00000060	20–181	Tangl.
Chloroform	0.00410	0.000015	22–181	"
Ethyl ether	0.00459	–		Ratz.
Methyl alcohol	0.0057	–	–	Drude.
Oils: Almond	0.00163	0.000026	–	Hasenöhrl.
Castor	0.01067	–	–	Heinke, 1896.
Olive	0.00364	–	–	" "
Paraffine	0.000738	0.0000072	–	Hasenöhrl.
Toluol	0.000921	–	0–13	Ratz.
"	0.000977	0.00000046	20–181	Tangl.
Water	0.004474	–	5–20	Heerwagen.
"	0.004583	0.0000117	0–76	Drude.
"	0.00436	–	4–25	Coolidge.
Meta-xylol	0.000817	–	20–181	Tangl.

(See Table 344 for the signification of the letters.)

TABLE 348.—Dielectric Constants of Liquified Gases.

A wave-length greater than 10000 centimeters is designated by ∞.

Substance.	Temp. °C.	Wave-length cm.	Dial. constant.	Authority.	Substance.	Temp. °C.	Wave-length cm.	Dial. constant.	Authority.
Air	−191	∞	1.432	1	Nitrous oxide N_2O	−88	∞	1.938	8
"	"	75	1.47–1.50	2	" "	−5	"	1.630	5
Ammonia	−34	75	21–23	3	" "	+5	"	1.578	"
"	14	130	16.2	4	" "	+15	"	1.520	"
Carbon dioxide	−5	∞	1.608	5	Oxygen	−182	"	1.491	9
" "	0	"	1.588	"	"	"	"	1.465	8
" "	+10	"	1.540	"	Sulphur dioxide	14.5	120	13.75	4
" "	+15	"	1.528	"	" "	20	∞	14.0	6
Chlorine	−60	"	2.150	"	" "	40	"	12.5	"
"	−20	"	2.030	"	" "	60	"	10.8	"
"	0	"	1.970	"	" "	80	"	9.2	"
"	+10	"	1.940	"	" "	100	"	7.8	"
"	0	"	2.08	6	" "	120	"	6.4	"
"	+14	100	1.88	4	" "	140	"	4.8	"
Cyanogen	23	84	2.52	7	Critical	154.2	"	2.1	"
Hydrocyanic acid	21	"	about 95	"					
Hydrogen sulph.	10	∞	5.93	6					
" "	50	"	4.92	"					
" "	90	"	3.76	"					

1 v. Pirani, 1903.
2 Bahn-Kiebitz, 1904.
3 Goodwin-Thompson, 1899.
4 Coolidge, 1899.
5 Linde, 1895.
6 Eversheim, 1904.
7 Schlundt, 1901.
8 Hasenöhrl, 1900.
9 Fleming-Dewar, 1896.

TABLE 349. — Standard Solutions for the Calibration of Apparatus for the Measuring of Dielectric Constants.

Turner.

Substance.	Diel. const. at 18°. λ = ∞.
Benzol	2.288
Meta-xylol	2.376
Ethyl ether	4.36[7]
Aniline	7.29[8]
Ethyl chloride	10.90
O-nitro toluol	27.71
Nitrobenzol	36.45
Water (conduct. 10^{-6})	81.07

Drude.

Acetone in benzol at 19°. λ = 75 cm.

Per cent by weight.	Density 16°.	Dielectric constant.	Temp. coefficient.
0	0.885	2.26	0.1%
20	0.866	5.10	0.3
40	0.847	8.43	0.4
60	0.830	12.1	0.5
80	0.813	16.2	0.5
100	0.797	20.5	0.6

Water in acetone at 19°. λ = 75 cm.

Per cent by weight.	Density 16°.	Dielectric constant.	Temp. coefficient.
0	0.797	20.5	0.6%
20	0.856	31.5	0.5
40	0.903	43.5	0.5
60	0.940	57.0	0.5
80	0.973	70.6	0.5
100	0.999	80.9	0.4

Nernst.

Ethyl alcohol in water at 19.5°. λ = ∞.

Per cent by weight.	Dielectric constant.
100	26.0
90	29.3
80	33.5
70	38.0
60	43.1

TABLE 350. — Dielectric Constants of Solids.

Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.
Asphalt	–	∞	2.68	1
Barium sulphate	–	75	10.2	2
Caoutchouc	–	∞	2.22	3
Diamond	–	"	16.5	1
"	–	75	5.50	2
Ebonite	–	∞	2.72	4
"	–	"	2.86	5
"	–	1000	2.55	6
Glass *	Density.			
Flint (extra heavy)	4.5	∞	9.90	7
Flint (very light)	2.87	"	6.61	7
Hard crown	2.48	"	6.96	7
Mirror	–	"	6.44–7.46	5
"	–	"	5.37–5.90	8
"	–	600	5.42–6.20	8
Lead (Powell)	3.0–3.5	∞	5.4–8.0	9
Jena Boron	–	"	5.5–8.1	10
Barium	–	"	7.8–8.5	10
Borosilicate	–	"	6.4–7.7	1
Gutta percha	–	–	3.3–4.9	11
Ice	Temp. —5	1200	2.85	12
"	—18	5000	3.16	13
"	—190	75	1.76–1.88	14

Substance.	Condition.	Wave-length, cm.	Dielectric constant.	Authority.
Iodine (cryst.)	Temp. 23	75	4.00	2
Lead chloride (powder)	–	"	42	2
" nitrate	–	"	16	2
" sulphate	–	"	28	2
" molybdenate	–	"	24	2
Marble (Carrara)	–	"	8.3	2
Mica	–	∞	5.66–5.97	5
"	–	"	5.80–6.62	15
Madras, brown		"	2.5–3.4	16
" green		"	3.9–5.5	16
" ruby	–	"	4.4	16
Bengal, yellow	–	"	2.8	16
" white	–	"	4.2	16
" ruby	–	"	4.2–4.7	16
Canadian amber	–	"	3.0	16
South America	–	"	5.9	16
Ozokerite (raw)	–	"	2.21	1
Paper (telephone)	–	"	2.0	17
" (cable)	–	"	2.0–2.5	1
Paraffine		"	2.46	18
"		"	2.32	19
"	Melting point. 44–46	"	2.10	20
"	54–56	"	2.14	20
"	74–76	"	2.16	20

References on p. 314.

* For the effect of temperature, see Gray-Dobbie, Pr. Roy. Soc. 63, 1898; 67, 1900.
" " " " wave-length, see K. F. Löwe, Wied. Ann. 66, 1898.

DIELECTRIC CONSTANTS (*continued*).

TABLE 350. — Dielectric Constants of Solids (*continued*).

Substance.	Condition.	Wave-length, cm.	Diel. constant.	Authority.
Paraffine	47.°6	61	2.16	21
"	56.°2	61	2.25	21
Phosphorus:				
Yellow	–	75	3.60	2
Solid		80	4.1	22
Liquid	–	80	3.85	22
Porcelain:				
Hard (Royal B'l'n)	–	∞	5.73	15
Seger " "	–	"	6.61	15
Figure " "	–	"	6.84	15
Selenium	–	"	7.44	1
"	–	75	6.60	2
"	–	∞	6.13	23
"	–	1000	6.14	23
Shellac	–	∞	3.10	4
"	–	"	2.95–3.73	24
"	–	"	3.67	25

Substance.	Condition.	Wave-length, cm.	Diel. constant.	Authority.
Sulphur				
Amorphous		∞	3.98	1
"	–	75	3.80	2
Cast, fresh	–	∞	4.22	1
" "	–	"	4.05	18
" "	–	75	3.95	2
Cast, old	–	∞	3.60	18
" "	–	75	3.90	2
Liquid	near melting-point	∞	3.42	1
Strontium sulphate	–	75	11.3	2
Thallium carbonate	–	75	17	2
" nitrate	–	75	16.5	2
Wood			dried	
Red beech	∥ fibres	∞	4.83–2.51	–
" "	⊥ "	"	7.73–3.63	–
Oak	∥ "	"	4.22–2.46	–
"	⊥ "	"	6.84–3.64	–

1 v. Pirani, 1903.
2 Schmidt, 1903.
3 Gordon, 1879.
4 Winklemann, 1889.
5 Elsas, 1891.
6 Ferry, 1897.
7 Hopkinson, 1891.
8 Arons-Rubens, 1891.
9 Gray-Dobbie, 1898.
10 Löwe, 1898.
11 (submarine-data).
12 Thwing, 1894.
13 Abegg, 1897.
14 Behn-Kiebitz, 1904.
15 Starke, 1897.
16 E. Wilson.
17 Campbell, 1906.
18 Fallinger, 1902.
19 Boltzmann, 1875.
20 Zietkowski, 1900.
21 Hormell, 1902.
22 Schlundt, 1904.
23 Vonwiller-Mason, 1907.
24 Wüllner, 1887.
25 Donle.

TABLE 351. — Dielectric Constants of Crystals.

$D\alpha$, $D\beta$, $D\gamma$ are the dielectric constants along the brachy, macro and vertical axes respectively.

Substance.	Wave-length, cm.	Diel. const. ⊥ Axis.	Diel. const. ∥ Axis.	Authority.
UNIAXIAL:				
Apatite	75	9.50	7.40	1
Beryl	∞	7.85	7.44	2
"	"	7.10	6.05	3
"	75	6.05	5.52	1
Calcspar	∞	8.49	7.56	4
"	"	8.78	8.29	5
Dolomite	75	7.80	6.80	1
Iceland spar	75	8.50	8.00	1
Quartz	∞	4.69	5.06	4
"	"	4.38	4.46	6
"	1000	4.27	4.34	6
"	75	4.32	4.60	1
Rutil (TiO_2)	75	89	173	1
Tourmaline	∞	7.13	6.54	4
"	75	6.75	5.65	1
Zircon	75	12.8	12.6	1

Substance.	Wave-length, cm.	$D\alpha$	$D\beta$	$D\gamma$	Authority.
RHOMBIC:					
Arragonite	∞	9.14	–	7.13	4
"	75	9.80	7.68	6.55	1
Barite	∞	6.97	10.09	7.00	4
"	75	7.65	12.20	7.70	1
Cœlestin	75	7.70	18.5	8.30	1
Cerussite	75	25.4	23.2	19.2	1
$MgSO_4 + 7H_2O$	∞	5.26	6.05	8.28	7
K_2SO_4	"	6.09	5.08	4.48	7
Rochelle salt	"	6.70	6.92	8.89	7
Sulphur	"	3.81	3.97	4.77	8
"	"	3.65	3.85	4.66	7
"	75	3.62	3.85	4.66	1
Topaz	75	6.65	6.70	6.30	1

1 Schmidt, 1903.
2 Starke, 1897.
3 Curie, 1889.
4 Fallinger, 1902.
5 v. Pirani, 1903.
6 Ferry, 1897.
7 Borel, 1893.
8 Boltzmann, 1875.

PERMEABILITY OF IRON.

TABLE 352. — Permeability of Iron Rings and Wire.

This table gives, for a few specimens of iron, the magnetic induction B, and permeability μ, corresponding to the magneto-motive forces H recorded in the first column. The first specimen is taken from a paper by Rowland,* and refers to a welded and annealed ring of "Burden's Best" wrought iron. The ring was 6.77 cms. in mean diameter, and the bar had a cross sectional area of 0.916 sq. cms. Specimens 2–4 are taken from a paper by Bosanquet,† and also refers to soft iron rings. The mean diameters were 21.5, 22.1, and 22.725 cms., and the thickness of the bars 2.535, 1.295, and .7544 cms. respectively. These experiments were intended to illustrate the effect of thickness of bar on the induction. Specimen 5 is from Ewing's book,‡ and refers to one of his own experiments on a soft iron wire .077 cms. diameter and 30.5 cms. long.

H	Specimen 1		2		3		4		5	
	B	μ	B	μ	B	μ	B	μ	B	μ
0.2	80	400	126	630	65	325	85	425	22	110
0.5	330	660	377	754	224	448	214	428	74	148
1.0	1450	1450	1449	1449	840	840	885	885	246	246
2.0	4840	2420	4564	2282	3533	1766	2417	1208	950	475
5.0	9880	1976	9900	1980	8293	1659	8884	1777	12430	2486
10.0	12970	1297	13023	1302	12540	1254	11388	1139	15020	1502
20.0	14740	737	14911	746	14710	735	13273	664	15790	789
50.0	16390	328	16217	324	16062	321	13890	278	–	–
100.0	–	–	17148	171	17900	179	14837	148	–	–

NOTE. — The comparatively high value of the magnetizing force required for maximum permeability when the specimen is a thin drawn wire is noticeable in specimen 5.

TABLE 353. — Permeability of Transformer Iron.§

This table contains the results of some experiments on transformers of the Westinghouse and Thomson-Houston types. Referring to the headings of the different columns, M is the total magneto-motive force applied to the iron; M/l the magneto-motive force per centimetre length of the iron circuit; B the total induction through the magnetizing coil; B/a the induction per square centimetre of the mean section of the iron core; M/B the magnetic reluctance of the iron circuit; Bl/Ma the permeability of the iron, a being taken as the mean cross section of the iron circuit as it exists in the transformer, which is thus slightly greater than the actual cross section of the iron.

(a) WESTINGHOUSE NO. 8 TRANSFORMERS (ABOUT 2500 WATTS CAPACITY).

M	$\frac{M}{l}$	First specimen.				Second specimen.			
		B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.597	218×10^3	1406	0.917×10^{-4}	2360	16×10^4	1032	1.25×10^{-4}	1730
40	1.194	587 "	3790	0.681 "	3120	49 "	3140	0.82 "	2640
60	1.791	878 "	5660	0.683 "	3180	82 "	5290	0.73 "	2970
80	2.338	1091 "	7040	0.734 "	2960	104 "	6710	0.77 "	2820
100	2.985	1219 "	7860	0.819 "	2640	118 "	7610	0.85 "	2560
120	3.582	1330 "	8580	0.903 "	2410	124 "	8000	0.97 "	2250
140	4.179	1405 "	9060	0.994 "	2186	131 "	8450	1.07 "	2036
160	4.776	1475 "	9510	1.090 "	2000	135 "	8710	1.18 "	1830
180	5.373	1532 "	9880	1.180 "	1850	140 "	9030	1.29 "	1690
200	5.970	1581 "	10200	1.270 "	1720	142 "	9160	1.41 "	1540
220	6.567	1618 "	10430	1.360 "	1590	144 "	9290	1.53 "	1410
260	7.761	1692 "	10910	1.540 "	1410	–	–		–

* "Phil. Mag." 4th series, vol. xlv. p. 151.
† Ibid. 5th series, vol. xix. p. 73.
‡ "Magnetic Induction in Iron and Other Metals."
§ T. Gray, from special experiments.

PERMEABILITY OF TRANSFORMER IRON.

(b) WESTINGHOUSE NO. 6 TRANSFORMERS (ABOUT :800 WATTS CAPACITY).

		First specimen.				Second specimen.			
M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.62	147×10^8	1320	1.36×10^{-4}	2140	215×10^8	1940	0.93×10^{-4}	3140
40	1.23	442 "	3980	0.91 "	3260	615 "	5540	0.64 "	4490
60	1.85	697 "	6280	0.86 "	3390	826 "	7440	0.72 "	4030
80	2.46	862 "	7770	0.93 "	3140	986 "	8880	0.81 "	3590
100	3.08	949 "	8550	1.05 "	2770	1050 "	9460	0.95 "	3060
120	3.70	1010 "	9106	1.19 "	2450	1100 "	9910	1.09 "	2670
140	4.31	1060 "	9550	1.33 "	2210	1140 "	10300	1.23 "	2430
160	4.93	1090 "	9820	1.47 "	1990	1170 "	10500	1.37 "	2180
180	5.55	1120 "	10100	1.61 "	1830	1190 "	10700	1.51 "	1970
200	6.16	1150 "	10400	1.74 "	1680	–	–		–

(c) WESTINGHOUSE NO. 4 TRANSFORMER (ABOUT 1200 WATTS CAPACITY).

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.69	147×10^8	1470	1.36×10^{-4}	2140
40	1.38	406 "	4066	0.98 "	2940
60	2.07	573 "	5730	1.05 "	2770
80	2.76	659 "	6590	1.21 "	2390
100	3.45	714 "	7140	1.40 "	2070
120	4.14	748 "	7490	1.60 "	1810
140	4.83	777 "	7770	1.80 "	1610

(d) THOMSON-HOUSTON 1500 WATTS TRANSFORMER.

M	$\frac{M}{l}$	B	$\frac{B}{a}$	$\frac{M}{B}$	$\frac{Bl}{Ma}$
20	0.42	70×10^8	1560	2.86×10^{-4}	3730
40	0.84	142 "	3160	2.81 "	3780
60	1.26	214 "	4770	2.81 "	3790
80	1.68	265 "	5910	3.02 "	3520
100	2.10	309 "	6890	3.24 "	3280
120	2.52	348 "	7760	3.45 "	3080
160	3.36	408 "	9100	3.92 "	2710
200	4.20	456 "	10200	4.39 "	2430
240	5.04	495 "	11000	4.87 "	2190
280	5.88	524 "	11690	5.35 "	1990
320	6.72	550 "	12270	5.82 "	1820
360	7.56	573 "	12780	6.29 "	1690
400	8.40	591 "	13180	6.78 "	1570
440	9.24	504 "	13470	7.28 "	1460

TABLE 354. — Magnetic Properties of Iron and Steel.

		Electrolytic Iron.	Good Cast Steel.	Poor Cast Steel.	Steel.	Cast Iron.	Electrical Sheets. Ordinary.	Electrical Sheets. Silicon Steel.
Chemical composition in per cent	C	0.024	0.044	0.56	0.99	3.11	0.036	0.036
	Si	0.004	0.004	0.18	0.10	3.27	0.330	3.90
	Mn	0.008	0.40	0.29	0.40	0.56	0.260	0.090
	P	0.008	0.044	0.076	0.04	1.05	0.040	0.009
	S	0.001	0.027	0.035	0.07	0.06	0.068	0.006
Coercive force . . .		2.83 [0.36]	1.51 [0.37]	7.1 (44.3)	16.7 (52.4)	11.4 [4.6]	[1.30]	[0.77]
Residual B		11400 [10800]	10600 [11000]	10500 (10500)	13000 (7500)	5100 [5350]	[9400]	[9850]
Maximum permeability		1850 [14400]	3550 [14800]	700 (170)	375 (110)	240 [600]	[3270]	[6130]
B for H=150 . . .		19200 [18900]	18800 [19100]	17400 (15400)	16700 (11700)	10400 [11000]	[18200]	[17550]
$4\pi I$ for saturation .		21620 [21630]	21420 [21420]	20600 (20200)	19800 (18000)	16400 [16800]	[20500]	[19260]

E. Gumlich, Zs. für Electrochemie, 15, p. 599; 1909.

Brackets indicate annealing at 800° C in vacuum. *Parentheses* indicate hardening by quenching from cherry-red.

TABLE 355. — Cast Iron in Intense Fields.

Soft Cast Iron.				Hard Cast Iron.			
H	B	I	μ	H	B	I	μ
114	9950	782	87.3	142	7860	614	55.4
172	10800	846	62.8	254	9700	752	38.2
433	13900	1070	32.1	339	10850	836	30.6
744	15750	1200	21.2	684	13050	983	19.1
1234	17300	1280	14.0	915	14050	1044	15.4
1820	18170	1300	10.0	1570	15900	1138	10.1
12700	31100	1465	2.5	2020	16800	1176	8.3
13550	32100	1475	2.4	10900	26540	1245	2.4
13800	32500	1488	2.4	13200	28600	1226	2.2
15100	33650	1472	2.2	14800	30200	1226	2.0

B. O. Peirce, Proc. Am. Acad. 44, 1909.

TABLE 356. — Corrections for Ring Specimens.

In the case of ring specimens, the average magnetizing force is not the value at the mean radius, the ratio of the two being given in the table. The flux density consequently is not uniform, and the measured hysteresis is less than it would be for a uniform distribution. This ratio is also given for the case of constant permeability, the values being applicable for magnetizations in the neighborhood of the maximum permeability. For higher magnetizations the flux density is more uniform, for lower it is less, and the correction greater.

Ratio of Radial Width to Diameter of Ring.	Ratio of Average H to H at Mean Radius. Rectangular Cross-section.	Ratio of Average H to H at Mean Radius. Circular Cross-section.	Ratio of Hysteresis for Uniform Distribution to Actual Hysteresis. Rectangular Cross-section.	Ratio of Hysteresis for Uniform Distribution to Actual Hysteresis. Circular Cross-section.
1/2	1.0986	1.0718	1.112	1.084
1/3	1.0397	1.0294	1.045	1.033
1/4	1.0216	1.0162	1.024	1.018
1/5	1.0137	1.0102	1.015	1.011
1/6	1.0094	1.0070	1.010	1.008
1/7	1.0069	1.0052	1.008	1.006
1/8	1.0052	1.0040	1.006	1.004
1/10	1.0033	1.0025	1.003	1.002
1/19	1.0009	1.0007	1.001	1.001

M. G. Lloyd, Bull. Bur. Standards, 5, p. 435; 1908.

COMPOSITION AND MAGNETIC

This table and Table 358 below are taken from a paper by Dr. Hopkinson * on the magnetic properties of iron and steel. which is stated in the paper to have been 240. The maximum magnetization is not tabulated; but as stated in the by 4π. "Coercive force" is the magnetizing force required to reduce the magnetization to zero. The "demag- previous magnetization in the opposite direction to the "maximum induction" stated in the table. The "energy which, however, was only found to agree roughly with the results of experiment.

No. of Test.	Description of specimen.	Temper.	Chemical analysis. Total Carbon.	Manganese.	Sulphur.	Silicon.	Phosphorus.	Other substances.
1	Wrought iron	Annealed	–	–	–	–	–	–
2	Malleable cast iron	"	–	–	–	–	–	–
3	Gray cast iron	–	–	–	–	–	–	–
4	Bessemer steel	–	0.045	0.200	0.030	None.	0.040	–
5	Whitworth mild steel	Annealed	0.090	0.153	0.016	"	0.042	–
6	" "	"	0.320	0.438	0.017	0.042	0.035	–
7	" "	Oil-hardened	"	"	"	"	"	–
8	" "	Annealed	0.890	0.165	0.005	0.081	0.019	–
9	" "	Oil-hardened	"	"	"	"	"	–
10	Hadfield's manganese steel	–	1.005	12.360	0.038	0.204	0.070	–
11	Manganese steel	As forged	0.674	4.730	0.023	0.608	0.078	–
12	" "	Annealed	"	"	"	"	"	–
13	" "	Oil-hardened	"	"	"	"	"	–
14	" "	As forged	1.298	8.740	0.024	0.094	0.072	–
15	" "	Annealed	"	"	"	"	"	
16	" "	Oil-hardened	"	"	"	"	"	–
17	Silicon steel	As forged	0.685	0.694	"	3.438	0.123	–
18	" "	Annealed	"	"	"	"	"	–
19	" "	Oil-hardened	"	"	"	"	"	
20	Chrome steel	As forged	0.532	0.393	0.020	0.220	0.041	0.621 Cr.
21	" "	Annealed	"	"	"	"	"	"
22	" "	Oil-hardened	"	"	"	"	"	"
23	" "	As forged	0.687	0.028	"	0.134	0.043	1.195 Cr.
24	" "	Annealed	"	"	"	"	"	"
25	" "	Oil-hardened	"	"	"	"	"	"
26	Tungsten steel	As forged	1.357	0.036	None.	0.043	0.047	4.649 W.
27	" "	Annealed	"	"	"	"	"	"
28	" "	Hardened in cold water	"	"	"	"	"	"
29	" "	Hardened in tepid water	"	"	"	"	"	"
30	" " (French)	Oil-hardened	0.511	0.625	None.	0.021	0.028	3.444 W.
31	" "	Very hard	0.855	0.312	–	0.151	0.089	2.353 W.
32	Gray cast iron	–	3.455	0.173	0.042	2.044	0.151	2.064 C.†
33	Mottled cast iron	–	2.581	0.610	0.105	1.476	0.435	1.477 C.†
34	White " "	–	2.036	0.386	0.467	0.764	0.458	–
35	Spiegeleisen	–	4.510	7.970	Trace.	0.502	0.128	–

* Phil. Trans. Roy. Soc. vol. 176.

† Graphitic carbon.

PROPERTIES OF IRON AND STEEL.

The numbers in the columns headed "magnetic properties" give the results for the highest magnetizing force used, paper, it may be obtained by subtracting the magnetizing force (240) from the maximum induction and then dividing netizing force" is the magnetizing force which had to be applied in order to leave no residual magnetization after dissipated" was calculated from the formula:— Energy dissipated = coercive force × maximum induction ÷ π

No. of Test.	Description of specimen.	Temper.	Specific electrical resistance.	Magnetic properties.				Energy dissipated per cycle.
				Maximum induction.	Residual induction.	Coercive force.	Demagnetizive force.	
1	Wrought iron	Annealed	.01378	18251	7248	2.30	-	13356
2	Malleable cast iron	"	.03254	12408	7479	8.80	-	34742
3	Gray cast iron	-	.10560	10783	3928	3.80	-	13037
4	Bessemer steel	-	.01050	18196	7860	2.96	-	17137
5	Whitworth mild steel	Annealed	.01080	19840	7080	1.63	-	10289
6	" "	"	.01446	18736	9840	6.73	-	40120
7	" "	Oil-hardened	.01390	18796	11040	11.00	-	65786
8	" "	Annealed	.01559	16120	10740	8.26	-	42366
9	" "	Oil-hardened	.01695	16120	8736	19.38	-	99401
10	Hadfield's manganese steel	-	.06554	310	-	-		-
11	Manganese steel	As forged	.05368	4623	2202	23.50	37.13	34567
12	" "	Annealed	.03928	10578	5848	33.86	46.10	113963
13	" "	Oil-hardened	.05556	4769	2158	27.64	40.29	41941
14	" "	As forged	.06993	747	-	-	-	-
15	" "	Annealed	.06316	1985	540	24.50	50.39	15474
16	" "	Oil-hardened	.07066	733	-	-	-	-
17	Silicon steel	As forged	.06163	15148	11073	9.49	12.60	45740
18	" "	Annealed	.06185	14701	8149	7.80	10.74	36485
19	" "	Oil-hardened	.06195	14696	8084	12.75	17.14	59619
20	Chrome steel	As forged	.02016	15778	9318	12.24	13.87	61439
21	" "	Annealed	.01942	14848	7570	8.98	12.24	42425
22	" "	Oil-hardened	.02708	13960	8595	38.15	48.45	169455
23	" "	As forged	.01791	14680	7568	18.40	22.03	85944
24	" "	Annealed	.01849	13233	6489	15.40	19.79	64842
25	" "	Oil-hardened	.03035	12868	7891	40.80	56.70	167050
26	Tungsten steel	As forged	.02249	15718	10144	15.71	17.75	78568
27	" "	Annealed	.02250	16498	11008	15.30	16.93	80315
28	" "	Hardened in cold water	.02274	-	-	-	-	-
29	" "	Hardened in tepid water	.02249	15610	9482	30.10	34.70	149500
30	" " (French)	Oil hardened	.03604	14480	8643	47.07	64.46	216864
31	" "	Very hard	.04427	12133	6818	51.20	70.69	197660
32	Gray cast iron	-	.11400	9148	3161	13.67	17.03	39789
33	Mottled cast iron	-	.06286	10546	5108	12.24	-	41072
34	White " "	-	.05661	9342	5554	12.24	20.40	36383
35	Spiegeleisen	-	.10520	385	77	-	-	-

PERMEABILITY OF SOME OF THE SPECIMENS IN TABLE 357.

TABLE 358.

This table gives the induction and the permeability for different values of the magnetizing force of some of the specimens in Table 357. The specimen numbers refer to the same table. The numbers in this table have been taken from the curves given by Dr. Hopkinson, and may therefore be slightly in error; they are the mean values for rising and falling magnetizations.

Magnetizing force. *H*	Specimen 1 (iron).		Specimen 8 (annealed steel).		Specimen 9 (same as 8 tempered).		Specimen 3 (cast iron).	
	B	μ	*B*	μ	*B*	μ	*B*	μ
1	–	–	–	–		–	265	265
2	200	100	–	–	–	–	700	350
3	–	–	–	–		–	1625	542
5	10050	2010	1525	300	750	150	3000	600
10	12550	1255	9000	900	1650	165	5000	500
20	14550	727	11500	575	5875	294	6000	300
30	15200	507	12650	422	9875	329	6500	217
40	15800	395	13300	332	11600	290	7100	177
50	16000	320	13800	276	12000	240	7350	149
70	16360	234	14350	205	13400	191	7900	113
100	16800	168	14900	149	14500	145	8500	85
150	17400	116	15700	105	15800	105	9500	63
200	17950	90	16100	80	16100	80	10190	51

Tables 359–363 give the results of some experiments by Du Bois,* on the magnetic properties of iron, nickel, and cobalt under strong magnetizing forces. The experiments were made on ovoids of the metals 18 centimeters long and 0.6 centimeters diameter. The specimens were as follows: (1) Soft Swedish iron carefully annealed and having a density 7.82. (2) Hard English cast steel yellow tempered at 230° C.; density 7.78. (3) Hard drawn best nickel containing 99 % Ni with some SiO_2 and traces of Fe and Cu; density 8.82. (4) Cast cobalt giving the following composition on analysis: Co = 93.1, Ni = 5.8, Fe = 0.8, Cu = 0.2, Si = 0.1, and C = 0.3. The specimen was very brittle and broke in the lathe, and hence contained a surfaced joint held together by clamps during the experiment. Referring to the columns, *H*, *B*, and μ have the same meaning as in the other tables, *S* is the magnetic moment per gram, and *I* the magnetic moment per cubic centimeter. *H* and *S* are taken from the curves published by Du Bois; the others have been calculated using the densities given.

MAGNETIC PROPERTIES OF SOFT IRON AT 0° AND 100° C.

TABLE 359.

Soft iron at 0° C.					Soft iron at 100° C.				
H	*S*	*I*	*B*	μ	*H*	*S*	*I*	*B*	μ
100	180.0	1408	17790	177.9	100	180.0	1402	17720	177.2
200	194.5	1521	19310	96.5	200	194.0	1511	19190	96.0
400	208.0	1627	20830	52.1	400	207.0	1613	20660	51.6
700	215.5	1685	21870	31.2	700	213.4	1663	21590	29.8
1000	218.0	1705	22420	22.4	1000	215.0	1674	22040	21.0
1200	218.5	1709	22670	18.9	1200	215.5	1679	22300	18.6

MAGNETIC PROPERTIES OF STEEL AT 0° AND 100° C.

TABLE 360.

Steel at 0° C.					Steel at 100° C.				
H	*S*	*I*	*B*	μ	*H*	*S*	*I*	*B*	μ
100	165.0	1283	16240	162.4	100	165.0	1278	16170	161.7
200	181.0	1408	17900	89.5	200	180.0	1395	17730	88.6
400	193.0	1500	19250	48.1	400	191.0	1480	19000	47.5
700	199.5	1552	20210	28.9	700	197.0	1527	19890	28.4
1000	203.5	1583	20900	20.9	1000	199.0	1543	20380	20.4
1200	205.0	1595	21240	17.7	1500	203.0	1573	21270	14.2
3750†	212.0	1650	24470	6.5	3000	205.5	1593	23020	7.7
					5000	208.0	1612	25260	5.1

* "Phil. Mag." 5 series, vol. xxix.

† The results in this and the other tables for forces above 1200 were not obtained from the ovoids above referred to, but from a small piece of the metal provided with a polished mirror surface and placed, with its polished face normal to the lines of force, between the poles of a powerful electromagnet. The induction was then inferred from the rotation of the plane of a polarized ray of red light reflected normally from the surface. (See Kerr's "Constants," p. 331.)

MAGNETIC PROPERTIES OF METALS.

TABLE 361. — Cobalt at 100° C.

H	S	I	B	μ
200	106	848	10850	54.2
300	116	928	11960	39.9
500	127	1016	13260	26.5
700	131	1048	13870	19.8
1000	134	1076	14520	14.5
1500	138	1104	15380	10.3
2500	143	1144	16870	6.7
4000	145	1164	18630	4.7
6000	147	1176	20780	3.5
9000	149	1192	23980	2.6
At 0° C. this specimen gave the following results:				
7900	154	1232	23380	3.0

TABLE 362. — Nickel at 100° C.

H	S	I	B	μ
100	35.0	309	3980	39.8
200	43.0	380	4966	24.8
300	46.0	406	5399	18.0
500	50.0	441	6043	12.1
700	51.5	454	6409	9.1
1000	53.0	468	6875	6.9
1500	56.0	494	7707	5.1
2500	58.4	515	8973	3.6
4000	59.0	520	10540	2.6
6000	59.2	522	12561	2.1
9000	59.4	524	15585	1.7
12000	59.6	526	18606	1.5
At 0° C. this specimen gave the following results:				
12300	67.5	595	19782	1.6

TABLE 363. — Magnetite.

The following results are given by Du Bois * for a specimen of magnetite.

H	I	B	μ
500	325	8361	16.7
1000	345	9041	9.0
2000	350	10084	5.0
12000	350	20084	1.7

Professor Ewing has investigated the effects of very intense fields on the induction in iron and other metals.† The results show that the intensity of magnetization does not increase much in iron after the field has reached an intensity of 1000 c. g. s. units, the increase of induction above this being almost the same as if the iron were not there, that is to say, dB/dH is practically unity. For hard steels, and particularly manganese steels, much higher forces are required to produce saturation. Hadfield's manganese steel seems to have nearly constant susceptibility up to a magnetizing force of 10,000. The following tables, taken from Ewing's papers, illustrate the effects of strong fields on iron and steel. The results for nickel and cobalt do not differ greatly from those given above.

TABLE 364. — Lowmoor Wrought Iron.

H	I	B	μ
3080	1680	24130	7.83
6450	1740	28300	4.39
10450	1730	32250	3.09
13600	1720	35200	2.59
16390	1630	36810	2.25
18760	1680	39900	2.13
18980	1730	40730	2.15

TABLE 365. — Vicker's Tool Steel.

H	I	B	μ
6210	1530	25480	4.10
9970	1570	29650	2.97
12120	1550	31620	2.60
14660	1580	34550	2.36
15530	1610	35820	2.31

TABLE 366. — Hadfield's Manganese Steel.

H	I	B	μ
1930	55	2620	1.36
2380	84	3430	1.44
3350	84	4400	1.31
5920	111	7310	1.24
6620	187	8970	1.35
7890	191	10290	1.30
8390	263	11690	1.39
9810	396	14790	1.51

TABLE 367. — Saturation Values for Steels of Different Kinds.

		H	I	B	μ
1	Bessemer steel containing about 0.4 per cent carbon . . .	17600	1770	39880	2.27
2	Siemens-Marten steel containing about 0.5 per cent carbon	18000	1660	38860	2.16
3	Crucible steel for making chisels, containing about 0.6 per cent carbon	19470	1480	38010	1.95
4	Finer quality of 3 containing about 0.8 per cent carbon . .	18330	1580	38190	2.08
5	Crucible steel containing 1 per cent carbon	19620	1440	37690	1.92
6	Whitworth's fluid-compressed steel	18700	1590	38710	2.07

* "Phil. Mag." 5 series, vol. xxix, 1890.

† "Phil. Trans. Roy. Soc." 1885 and 1889.

TABLE 368.—MAGNETIC PROPERTIES OF IRON IN VERY WEAK FIELDS.

The effect of very small magnetizing forces has been studied by C. Baur * and by Lord Rayleigh.† The following short table is taken from Baur's paper, and is taken by him to indicate that the susceptibility is finite for zero values of H and for a finite range increases in simple proportion to H. He gives the formula $k = 15 + 100 H$, or $I = 15 H + 100 H^2$. The experiments were made on an annealed ring of round bar 1.013 cms. radius, the ring having a radius of 9.432 cms. Lord Rayleigh's results for an iron wire not annealed give $k = 6.4 + 5.1 H$, or $I = 6.4 H + 5.1 H^2$. The forces were reduced as low as 0.00004 c. g. s., the relation of k to H remaining constant.

First experiment.			Second experiment.	
H	k	I	H	k
.01580	16.46	2.63	.0130	15.50
.03081	17.65	5.47	.0847	18.38
.07083	23.00	16.33	.0946	20.49
.13188	28.90	38.15	.1864	25.07
.23011	39.81	91.56	.2903	32.40
.38422	58.56	224.87	.3397	35.20

TABLES 369, 370.—DISSIPATION OF ENERGY IN CYCLIC MAGNETIZATION OF MAGNETIC SUBSTANCES.

When a piece of iron or other magnetic metal is made to pass through a closed cycle of magnetization dissipation of energy results. Let us suppose the iron to pass from zero magnetization to strong magnetization in one direction and then gradually back through zero to strong magnetization in the other direction and thence back to zero, and this operation to be repeated several times. The iron will be found to assume the same magnetization when the same magnetizing force is reached from the same direction of change, but not when it is reached from the other direction. This has been long known, and is particularly well illustrated in the permanency of hard steel magnets. That this fact involves a dissipation of energy which can be calculated from the open loop formed by the curves giving the relation of magnetization to magnetizing force was pointed out by Warburg ‡ in 1881, reference being made to experiments of Thomson, § where such curves are illustrated for magnetism, and to E. Cohn, ‖ where similar curves are given for thermo-electricity. The results of a number of experiments and calculations of the energy dissipated are given by Warburg. The subject was investigated about the same time by Ewing, who published results somewhat later. ¶ Extensive investigations have since been made by a number of investigators.

TABLE 369.—Soft Iron Wire.

(From Ewing's 1885 paper.)

Total induction per sq. cm. B	Dissipation of energy in ergs per cu. cm.	Horse-power wasted per ton at 100 cycles per sec.
2000	420	0.74
3000	800	1.41
4000	1230	2.18
5000	1700	3.01
6000	2200	3.89
7000	2760	4.88
8000	3450	6.10
9000	4200	7.43
10000	5000	8.84
11000	5820	10.30
12000	6720	11.89
13000	7650	13.53
14000	8650	15.30
15000	9670	17.10

TABLE 370.—Cable Transformers.

This table gives the results obtained by Alexander Siemens with one of Siemens' cable transformers. The transformer core consisted of 900 soft iron wires 1 mm. diameter and 6 meters long.** The dissipation of energy in watts is for 100 complete cycles per second.

Mean maximum induction density in core. B	Total observed dissipation of energy in the core in watts per 112 lbs.	Calculated eddy current loss in watts per 112 lbs.	Hysteresis loss of energy in watts per 112 lbs.	Hysteresis loss of energy in ergs per cu. cm. per cycle.
1000	43.2	4	39.2	602
2000	96.2	16	80.2	1231
3000	158.0	36	122.0	1874
4000	231.2	64	167.2	2566
5000	309.5	100	209.5	3217
6000	390.1	144	246.1	3779

* "Wied. Ann." vol. xi.
† "Phil. Mag." vol. xxiii.
‡ "Wied. Ann." vol. xiii. p. 141.
§ "Phil. Trans. Roy. Soc." vol. 175.
‖ "Wied. Ann." vol. 6.
¶ "Proc. Roy. Soc." 1882, and "Trans. Roy. Soc." 1885.
** "Proc. Inst. of Elect. Eng." Lond., 1892.

DEMAGNETIZING FACTORS FOR RODS.

TABLE 371.

H = true intensity of magnetizing field, H' = intensity of applied field, I = intensity of magnetization, $H = H' - NI$.

Shuddemagen says: The demagnetizing factor is not a constant, falling for highest values of I to about 1/7 the value when unsaturated; for values of B ($= H + 4\pi I$) less than 10000, N is approximately constant; using a solenoid wound on an insulating tube, or a tube of split brass, the reversal method gives values for N which are considerably lower than those given by the step-by-step method; if the solenoid is wound on a thick brass tube, the two methods practically agree.

Ratio of Length to Diameter.	Values of $N \times 10^4$.						
	Ellipsoid.	Cylinder.					
		Uniform Magnetization.	Magnetometric Method (Mann).	Ballistic Step Method.			
				Dubois.	Shuddemagen for Range of Practical Constancy.		
				Diameter.			
				0.158 cm.	0.3175 cm.	1.111 cm.	1.905 cm.
5	7015	-	6800				
10	2549	630	2550	2160	-	-	1960
15	1350	280	1400	1206	-		1075
20	848	160	898	775	-	-	671
30	432	70	460	393	388	350	343
40	266	39	274	238	234	212	209
50	181	25	182	162	160	145	149
60	132	18	131	118	116	106	106
70	101	13	99	89	88		
80	80	9.8	78	69	69	66	63
90	65	7.8	63	55	56		
100	54	6.3	51.8	45	46	41	41
150	26	2.8	25.1	20	23	21	21
200	16	1.57	15.2	11	12.5	11	11
300	7.5	0.70	7.5	5.0			
400	4.5	0.39	-	2.8			

C. R. Mann, Physical Review, 3, p. 359; 1896.
H. DuBois, Wied. Ann. 7, p. 942; 1902.
C. L. B. Shuddemagen, Proc. Am. Acad. Arts and Sci. 43, p. 185, 1907 (Bibliography).

TABLE 372.

Shuddemagen also gives the following, where B is determined by the step method and $H = H' - KB$.

Ratio of Length to Diameter.	Values of $K \times 10^4$.	
	Diameter 0.3175 cm.	Diameter 1.1 to 2.0 cm.
15	-	85.2
20	-	53.3
25	-	36.6
30	30.9	27.3
40	18.6	16.6
50	12.7	11.6
60	9.25	8.45
80	5.5	5.05
100	3.66	3.26
150	1.83	1.67

DISSIPATION OF ENERGY IN THE CYCLIC MAGNETIZATION OF VARIOUS SUBSTANCES.

C. P. Steinmetz concludes from his experiments * that the dissipation of energy due to hysteresis in magnetic metals can be expressed by the formula $e = aB^{1.6}$, where e is the energy dissipated and a a constant. He also concludes that the dissipation is the same for the same range of induction, no matter what the absolute value of the terminal inductions may be. His experiments show this to be nearly true when the induction does not exceed $\pm$ 15000 c. g. s. units per sq. cm. It is possible that, if metallic induction only be taken, this may be true up to saturation; but it is not likely to be found to hold for total inductions much above the saturation value of the metal. The law of variation of dissipation with induction range in the cycle, stated in the above formula, is also subject to verification.†

Values of Constant *a*.

The following table gives the values of the constant *a* as found by Steinmetz for a number of different specimens. The data are taken from his second paper.

Number of specimen.	Kind of material.	Description of specimen.	Value of *a*.
1	Iron . .	Norway iron	.00227
2	" . .	Wrought bar	.00326
3	" . .	Commercial ferrotype plate	.00548
4	" . .	Annealed " "	.00458
5	" . .	Thin tin plate	.00286
6	" . .	Medium thickness tin plate	.00425
7	Steel . .	Soft galvanized wire	.00349
8	" . .	Annealed cast steel	.00848
9	" . .	Soft annealed cast steel	.00457
10	" . .	Very soft annealed cast steel	.00318
11	" . .	Same as 8 tempered in cold water	.02792
12	" .	Tool steel glass hard tempered in water . .	.07476
13	" . .	" " tempered in oil	.02670
14	" . .	" " annealed	.01899
15	" . .	Same as 12, 13, and 14, after having been subjected to an alternating m. m. f. of from 4000 to 6000 ampere turns for demagnetization . . .	.06130
16	" . .		.02700
17	" . .		.01445
18	Cast iron .	Gray cast iron	.01300
19	" " .	" " " containing $\frac{1}{8}$ % aluminium . .	.01365
20	" " .	" " " " $\frac{1}{2}$ % " . .	.01459
21	Magnetite .	A square rod 6 sq. cms. section and 6.5 cms. long, from the Tilly Foster mines, Brewsters, Putnam County, New York, stated to be a very pure sample	.02348
22	Nickel .	Soft wire	.0122
23	" .	Annealed wire, calculated by Steinmetz from Ewing's experiments	.0156
24	" .	Hardened, also from Ewing's experiments . .	.0385
25	Cobalt .	Rod containing about 2 % of iron, also calculated from Ewing's experiments by Steinmetz . .	.0120
26	Iron filings	Consisted of thin needle-like chips obtained by milling grooves about 8 mm. wide across a pile of thin sheets clamped together. About 30 % by volume of the specimen was iron.	
		1st experiment, continuous cyclic variation of m. m. f. 180 cycles per second	.0457
		2d experiment, 114 cycles per second . . .	.0396
		3d " 79–91 cycles per second . . .	.0373

* "Trans. Am. Inst. Elect. Eng." January and September, 1892.
† See T. Gray, "Proc. Roy. Soc." vol. lvi.

Table 374.

ENERGY LOSSES IN TRANSFORMER STEELS.

Determined by the wattmeter method.

Loss per cycle per $cc = AB^x + bnB^y$, where B = flux density in gausses and n = frequency in cycles per second. x shows the variation of hysteresis with B between 5000 and 10000 gausses, and y the same for eddy currents.

Designation.	Thickness. cm.	Ergs per Gramme per Cycle. 10000 Gausses. Hysteresis.	10000 Gausses. Eddy Currents at 60~	5000 Gausses. Hysteresis.	5000 Gausses. Eddy Currents at 60~	x	y	a	Watts per Pound at 60 Cycles and 10000 Gausses. Eddy Current Loss for Gage No. 29.‡	Hysteresis.	Total.
Unannealed											
A	0.0399	1599	186	562	46	1.51	2.02	0.00490	0.41	4.35	4.76
B	.0326	1156	134	384	36	1.59	1.89	.00358	0.44	3.14	3.58
C	.0422	1032	242	356	70	1.51	1.79	.00319	0.47	2.81	3.28
D	.0381	1009	184	353	48	1.52	1.94	.00312	0.44	2.74	3.18
Annealed											
E	.0476	735	236	246	58	1.58	2.02	.00227	0.36	2.00	2.36
F	.0280	666	100	220	27	1.60	1.88	.00206	0.44	1.81	2.25
G	.0394	563	210	193	54	1.54	1.96	.00174	0.47	1.53	2.00
H*	.0307	412	146	138.5	39	1.58	1.90	.00127	0.54	1.12	1.66
J	.0318	341	202	111.5	55	1.62	1.88	.00105	0.70	0.93	1.63
K*	.0282	394	124	130	32	1.61	1.90	.00122	0.54	1.07	1.61
L	.0346	381	184	125	50	1.61	1.88	.00118	0.535	1.035	1.57
B	.0338	354	200	116	57	1.61	1.81	.00110	0.61	0.96	1.57
M	.0335	372	178	127	46	1.55	1.95	.00115	0.55	1.01	1.56
N	.0340	321	210	105	56	1.62	1.90	.00099	0.63	0.87	1.50
P	.0437	334	184	107	50	1.64	1.88	.00103	0.34	0.91	1.25
Silicon steels											
Q†	.0361	303	54	98	15	1.63	–	.00094	0.14	0.825	0.965
R	.0315	288	42	93	11	1.64	–	.00089	0.15	0.78	0.93
S	.0452	278	72	90	18	1.63	–	.00086	0.12	0.755	0.875
T	.0338	250	60	78	18	1.68	–	.00077	0.18	0.68	0.86
U	.0346	270	42	86	12	1.66	–	.00084	0.12	0.735	0.855
V*	.0310	251.5	47	79	13	1.68	–	.00078	0.17	0.685	0.855
W*	.0305	197	43	62.3	12.4	1.67	–	.00061	0.16	0.535	0.695
X	.0430	200	65	64.2	16.6	1.65	–	.00062	0.12	0.545	0.665

* German. † English.

‡ In order to make a fair comparison, the eddy current loss has been computed for a thickness of 0.0357 cm. (Gage No. 29), assuming the loss proportional to the thickness.

Lloyd and Fisher, Bull. Bur. Standards, 5, p. 453; 1909.

Note. — For formulæ and tables for the calculation of mutual and self inductance see Bulletin Bureau of Standards, vol. 8, p. 1–237, 1912.

MAGNETO-OPTIC ROTATION.

Faraday discovered that, when a piece of heavy glass is placed in magnetic field and a beam of plane polarized light passed through it in a direction parallel to the lines of magnetic force, the plane of polarization of the beam is rotated. This was subsequently found to be the case with a large number of substances, but the amount of the rotation was found to depend on the kind of matter and its physical condition, and on the strength of the magnetic field and the wave-length of the polarized light. Verdet's experiments agree fairly well with the formula—

$$\theta = clH\left(r - \lambda\frac{dr}{d\lambda}\right)\frac{r^2}{\lambda^2},$$

where c is a constant depending on the substance used, l the length of the path through the substance, H the intensity of the component of the magnetic field in the direction of the path of the beam, r the index of refraction, and λ the wave-length of the light in air. If H be different, at different parts of the path, lH is to be taken as the integral of the variation of magnetic potential between the two ends of the medium. Calling this difference of potential v, we may write $\theta = Av$, where A is constant for the same substance, kept under the same physical conditions, when the one kind of light is used. The constant A has been called "Verdet's constant," * and a number of values of it are given in Tables 376–380. For variation with temperature the following formula is given by Bichat:—

$$R = R_0\,(1 - 0.00104\,t - 0.000014\,t^2),$$

which has been used to reduce some of the results given in the table to the temperature corresponding to a given measured density. For change of wave-length the following approximate formula, given by Verdet and Becquerel, may be used:—

$$\frac{\theta_1}{\theta_2} = \frac{\mu_1^2(\mu_1^2 - 1)\lambda_2^2}{\mu_2^2(\mu_2^2 - 1)\lambda_1^2},$$

where μ is index of refraction and λ wave-length of light.

A large number of measurements of what has been called molecular rotation have been made, particularly for organic substances. These numbers are not given in the table, but numbers proportional to molecular rotation may be derived from Verdet's constant by multiplying in the ratio of the molecular weight to the density. The densities and chemical formulæ are given in the table. In the case of solutions, it has been usual to assume that the total rotation is simply the algebraic sum of the rotations which would be given by the solvent and dissolved substance, or substances, separately; and hence that determinations of the rotary power of the solvent medium and of the solution enable the rotary power of the dissolved substance to be calculated. Experiments by Quincke and others do not support this view, as very different results are obtained from different degrees of saturation and from different solvent media. No results thus calculated have been given in the table, but the qualitative result, as to the sign of the rotation produced by a salt, may be inferred from the table. For example, if a solution of a salt in water gives Verdet's constant less than 0.0130 at 20° C., Verdet's constant for the salt is negative.

The table has been for the most part compiled from the experiments of Verdet,† H. Becquerel,‡ Quincke,§ Koepsel,‖ Arons,¶ Kundt,** Jahn,†† Schönrock,‡‡ Gordon,§§ Rayleigh and Sidgewick,‖‖ Perkin,¶¶ Bichat.***

As a basis for calculation, Verdet's constant for carbon disulphide and the sodium line D has been taken as 0.0420 and for water as 0.0130 at 20° C.

* The constancy of this quantity has been verified through a wide range of variation of magnetic field by H. E. J. G. Du Bois (Wied. Ann. vol. 35), p. 137, 1888.
† "Ann. de Chim. et de Phys." [3] vol. 52, p. 129, 1858.
‡ "Ann. de Chim. et de Phys." [5] vol. 12; "C. R." vols. 90, p. 1407, 1880, and 100, p. 1374, 1885.
§ "Wied. Ann." vol. 24, p. 606, 1885.
‖ "Wied. Ann." vol. 26, p. 456, 1885.
¶ "Wied. Ann." vol. 24, p. 161, 1885.
** "Wied. Ann." vols. 23, p. 228, 1884, and 27, p. 191, 1886.
†† "Wied. Ann." vol. 43, p. 280, 1891.
‡‡ "Zeits. für Phys. Chem." vol. 11, p. 753, 1893.
§§ "Proc. Roy. Soc." 36, p. 4, 1883.
‖‖ "Phil. Trans. R. S." 176, p. 343, 1885.
¶¶ "Jour. Chem. Soc."
*** "Jour. de Phys." vols. 8, p. 204, 1879, and 9, p. 204 and p. 275, 1880.

TABLE 376.

MAGNETO-OPTIC ROTATION.

Solids.

Substance.	Formula.	Wave-length.	Verdet's Constant. Minutes.	Temp. C.	Authority.
		μ			
Amber		0.589	0.0095	18–20°	Quincke.
Blende	ZnS	"	0.2234	15	Becquerel.
Diamond	C	"	0.0127	15	"
Lead borate	PbB_2O_4	"	0.0600	15	"
Selenium	Se	0.687	0.4625	15	"
Sodium borate	$Na_2B_4O_7$	0.589	0.0170	15	"
Ziqueline	Cu_2O	0.687	0.5908	15	"
Fluorite	$CaFl_2$	0.2534	0.05989	20	Meyer, Ann. der Physik, 30, 1909.
		.3655	.02526	"	
		.4358	.01717	"	
		.4916	.01329	"	
		.589	.00897	"	
		1.00	.00300	"	
		2.50	.00049	"	
		3.00	.00030	"	
Glass, Jena: Medium phosphate crn.		0.589	0.0161	18	DuBois, Wied. Ann. 51, 1894.
Heavy crown, O1143		"	0.0220	"	
Light flint, O451		"	0.0317	"	
Heavy flint O500		"	0.0608	"	
" " S163		"	0.0888	"	
Zeiss, Ultraviolet		0.313	0.0674	16	Landau, Phys. ZS. 9, 1908.
"		0.405	.0369	"	
"		0.436	.0311	"	
Quartz, along axis, i.e., plate cut ⊥ to axis	SiO_2	0.2194	0.1587	20	Borel, Arch. sc. phys. 16, 1903.
		.2573	.1079	"	
		.3609	.04617	"	
		.4800	.02574	"	
		.5892	.01664	"	
		.6439	.01368	"	
Rock salt	NaCl	0.2599	0.2708	20	Meyer, as above.
		.3100	.1561	"	
		.4046	.0775	"	
		.4916	.0483	"	
		.6708	.0245	"	
		1.00	.01050	"	
		2.00	.00262	"	
		4.00	.00069	"	
Sugar, cane: along axis IIA	$C_{12}H_{22}O_{11}$	0.451	.0122	20	Voigt, Phys. ZS. 9, 1908.
		.540	.0076	"	
		.626	.0066	"	
axis IIA[1]	–	0.451	0.0129	"	
		.540	.0084	"	
		.626	.0075	"	
Sylvine	KCl	0.4358	0.0534	20	Meyer, as above.
		.5461	.0316	"	
		.6708	.02012	"	
		.90	.01051	"	
		1.20	.00608	"	
		2.00	.00207	"	
		4.00	.00054	"	

Table 377.

MAGNETO-OPTIC ROTATION.

Liquids: Verdet's Constant for $\lambda = 0.589\mu$.

Substance.	Chemical formula.	Density in grams per c. c.	Verdet's constant in minutes.	Temp. C.	Authority.
Acetone	C_3H_6O	0.7947	0.0113	20°	Jahn.
Acids: Acetic	$C_2H_4O_2$	1.0561	.0105	21	Perkin.
" Butyric	$C_4H_8O_2$	0.9663	.0116	15	"
" Formic	CH_2O_2	1.2273	.0105	"	"
" Hydrochloric	HCl	1.2072	.0224	"	"
" Hydrobromic	HBr	1.7859	.0343	"	"
" Hydroiodic	HI	1.9473	.0515	"	"
" Nitric	HNO_3	1.5190	.0070	13	"
" Sulphuric	H_2SO_4	—	.0121	15	Becquerel.
Alcohols: Amyl	$C_5H_{11}OH$	0.8107	.0128	20	Jahn.
" Butyl	C_4H_9OH	0.8021	.0124	"	"
" Ethyl	C_2H_5OH	0.7900	.0112	"	"
" Methyl	CH_3OH	0.7920	.0093	"	"
" Propyl	C_3H_7OH	0.8042	.0120	"	"
Benzol	C_6H_6	0.8786	.0297	"	"
Bromides: Bromoform	$CHBr_3$	2.9021	.0317	15	Perkin.
" Ethyl	C_2H_5Br	1.4486	.0183	"	"
" Ethylene	$C_2H_4Br_2$	2.1871	.0268	"	"
" Methyl	CH_3Br	1.7331	.0205	0	"
" Methylene	CH_2Br_2	2.4971	.0276	15	"
Carbon bisulphide	CS_2	—	.0433	0	Gordon.
" "	"	—	.0420	18	Rayleigh.
Chlorides: Amyl	$CHCl$	0.8740	.0140	20	Jahn.
" Arsenic	$AsCl_3$	—	.0422	15	Becquerel.
" Carbon	CCl_4	—	.0321	"	"
" Chloroform	$CHCl_3$	1.4823	.0164	20	Jahn.
" Ethyl	C_2H_5Cl	0.9169	0.0138	6	Perkin.
" Ethylene	$C_2H_4Cl_2$	1.2589	.0166	15	"
" Methyl	CH_3Cl	—	.0170	"	Becquerel.
" Methylene	CH_2Cl_2	1.3361	.0162	"	Perkin.
" Sulphur bi-	S_2Cl_2	—	.0393	"	Becquerel.
" Tin tetra	$SnCl_4$	—	.0151	"	"
" Zinc bi-	$ZnCl_2$	—	.0437	"	"
Iodides: Ethyl	C_2H_5I	1.9417	.0296	"	Perkin.
" Methyl	CH_3I	2.2832	.0336	"	"
" Propyl	C_3H_7I	1.7658	.0271	"	"
Nitrates: Ethyl	$C_2H_5O.NO_2$	1.1149	.0091	"	"
" Methyl	$CH_3O.NO_2$	1.2157	.0078	"	"
" Propyl	$C_3H_7O.NO_2$	1.0622	.0100	"	"
Paraffins: Heptane	C_7H_{16}	0.6880	.0125	"	"
" Hexane	C_6H_{14}	0.6743	.0125	"	"
" Pentane	C_5H_{12}	0.6332	.0118	"	"
Phosphorus, melted	P	—	.1316	33	Becquerel.
Sulphur, melted	S	—	.0803	114	"
Toluene	C_7H_8	0.8581	.0269	28	Schönrock.
Water, $\lambda = 0.2496\ \mu$	H_2O		.1042		See Meyer,
0.275			.0776		Ann. der
0.3609			.0384		Physik, 30,
0.4046			.0293		1909. Meas-
0.500			.0184		ures by
0.589			.0131		Landau,
0.700			.0091		Siertsema,
1.000			.00410		Ingersoll.
1.300			.00264		
Xylene	C_8H_{10}	0.8746	.0263	27	Schönrock.

MAGNETO-OPTIC ROTATION.

Solutions of acids and salts in water. Verdet's constant for $\lambda = 0.589\mu$.

Chemical formula.	Density, grams per c. c.	Verdet's constant in minutes.	Temp. C.	*	Chemical formula.	Density, grams per c. c.	Verdet's constant in minutes.	Temp. C.	*
C_8H_8O	0.9715	0.0129	20°	J	LiCl	1.0619	0.0145	20°	J
HBr	1.3775	0.0244	"	P	"	1.0316	0.0143	"	"
"	1.1163	0.0168	"	"	$MnCl_2$	1.1966	0.0167	15	B
HCl	1.1573	0.0204	"	"	"	1.0876	0.0150	"	"
"	1.0762	0.0168	"	"	$HgCl_2$	1.0381	0.0137	16	S
"	1.0158	0.0140	"	J	"	1.0349	0.0137	"	"
HI	1.9057	0.0499	"	P	$NiCl_2$	1.4685	0.0270	15	B
"	1.4495	0.0323	"	"	"	1.2432	0.0196	"	"
"	1.1760	0.0205	"	"	"	1.1233	0.0162	"	"
HNO_3	1.3560	0.0105	"	"	KCl	1.6000	0.0163	"	"
NH_3	0.8918	0.0153	15	"	"	1.0732	0.0148	20	J
NH_4Br	1.2805	0.0226	"	"	NaCl	1.2051	0.0180	15	B
"	1.1576	0.0186	"	"	"	1.0546	0.0144	"	"
$BaBr_2$	1.5399	0.0215	20	J	"	1.0418	0.0144	"	J
"	1.2855	0.0176	"	"	$SrCl_2$	1.1921	0.0162	"	"
$CdBr_2$	1.3291	0.0192	"	"	"	1.0877	0.0146	"	"
"	1.1608	0.0162	"	"	$SnCl_2$	1.3280	0.0266	15	V
$CaBr_2$	1.2491	0.0189	"	"	"	1.1112	0.0175	"	"
"	1.1337	0.0164	"	"	$ZnCl_2$	1.2851	0.0196	"	"
KBr	1.1424	0.0163	"	"	"	1.1595	0.0161	"	"
"	1.0876	0.0151	"	"	K_2CrO_4	1.3598	0.0098	"	"
NaBr	1.1351	0.0165	"	"	$K_2Cr_2O_7$	1.0786	0.0126	"	"
"	1.0824	0.0152	"	"	$Hg(CN)_2$	1.0638	0.0136	16	S
$SrBr_2$	1.2901	0.0186	"	"	"	1.0605	0.0135	"	"
"	1.1416	0.0159	"	"	NH_4I	1.5948	0.0396	15	P
K_2CO_3	1.1906	0.0140	20	"	"	1.5109	0.0358	"	"
Na_2CO_3	1.1006	0.0140	"	"	"	1.2341	0.0235	"	"
"	1.0564	0.0137	"	"	CdI	1.5156	0.0291	20	J
NH_4Cl	1.0718	0.0178	15	V	"	1.1521	0.0177	"	"
$BaCl_2$	1.2897	0.0168	20	J	KI	1.6743	0.0338	15	B
"	1.1338	0.0149	"	"	"	1.3398	0.0237	"	"
$CdCl_2$	1.3179	0.0185	"	"	"	1.1705	0.0182	"	"
"	1.2755	0.0179	"	"	NaI	1.1939	0.0200	"	J
"	1.1732	0.0160	"	"	"	1.1191	0.0175	"	"
"	1.1531	0.0157	"	"	NH_4NO_3	1.2803	0.0121	15	P
$CaCl_2$	1.1504	0.0165	"	"	KNO_3	1.0634	0.0130	20	J
"	1.0832	0.0152	"	"	$NaNO_3$	1.1112	0.0131	"	"
$CuCl_2$	1.5158	0.0221	15	B	$U_2O_8N_2O_5$	2.0267	0.0053	"	B
"	1.1330	0.0156	"	"	"	1.1963	0.0115	"	"
$FeCl_2$	1.4331	0.0025	15	"	$(NH_4)_2SO_4$	1.2286	0.0140	15	P
"	1.2141	0.0099	"	"	$NH_4.HSO_4$	1.4417	0.0085	"	"
"	1.1093	0.0118	"	"	$BaSO_4$	1.1788	0.0134	20	J
Fe_2Cl_6	1.6933	—0.2026	"	"	"	1.0938	0.0133	"	"
"	1.5315	—0.1140	"	"	$CdSO_4$	1.1762	0.0139	"	"
"	1.3230	—0.0348	"	"	"	1.0890	0.0136	"	"
"	1.1681	—0.0015	"	"	Li_2SO_4	1.1762	0.0137	"	"
"	1.0864	0.0081	"	"	$MnSO_4$	1.2441	0.0138	"	"
"	1.0445	0.0113	"	"	K_2SO_4	1.0475	0.0133	"	"
"	1.0232	0.0122	"	"	$NaSO_4$	1.0661	0.0135	"	"

* J, Jahn, P, Perkin, V, Verdet, B, Becquerel, S, Schönrock; see p. 326 for references.

TABLE 379.—Magneto-Optic Rotation.

Gases.

Substance.	Pressure.	Temp.	Verdet's constant in minutes.	Authority.
Atmospheric air	Atmospheric	Ordinary	6.83×10^{-6}	Becquerel.
Carbon dioxide	"	"	13.00 "	"
Carbon disulphide	74 cms.	70° C.	23.49 "	Bichat.
Ethylene	Atmospheric	Ordinary	34.48 "	Becquerel.
Nitrogen	"	"	6.92 "	"
Nitrous oxide	"	"	16.90 "	"
Oxygen	"	"	6.28 "	"
Sulphur dioxide	"	"	31.39 "	"
" "	246 cms.	20° C.	38.40 "	Bichat.

See also Siertsema, Ziting. Kon. Akad. Watt., Amsterdam, 7, 1899; 8, 1900.

Du Bois shows that in the case of substances like iron, nickel, and cobalt which have a variable magnetic susceptibility the expression in Verdet's equation, which is constant for substances of constant susceptibility, requires to be divided by the susceptibility to obtain a constant. For this expression he proposes the name "Kundt's constant." These experiments of Kundt and Du Bois show that it is not the difference of magnetic potential between the two ends of the medium, but the product of the length of the medium and the induction per unit area, which controls the amount of rotation of the beam.

TABLE 380.—Verdet's and Kundt's Constants.

The following short table is quoted from Du Bois' paper. The quantities are stated in c. g. s. measure, circular measure (radians) being used in the expression of "Verdet's constant" and "Kundt's constant."

Name of substance.	Magnetic susceptibility.	Verdet's constant.		Wave-length of light in cms.	Kundt's constant.
		Number.	Authority.		
Cobalt	-	-	-	6.44×10^{-5}	3.99
Nickel	-	-	-	"	3.15
Iron	-	-	-	6.56 "	2.63
Oxygen: 1 atmo.	$+0.0126 \times 10^{-6}$	0.000179×10^{-6}	Becquerel.	5.89 "	0.014
Sulphur dioxide	—0.0751 "	0.302 "	"	"	—4.00
Water	—0.0694 "	0.377 "	Arons	"	—5.4
Nitric acid	—0.0633 "	0.356 "	Becquerel.	"	—5.6
Alcohol	—0.0566 "	0.330 "	De la Rive.	"	—5.8
Ether	—0.0541 "	0.315 "	"	"	—5.8
Arsenic chloride	—0.0876 "	1.222 "	Becquerel.	"	—14.9
Carbon disulphide	—0.0716 "	1.222 "	Rayleigh.	"	—17.1
Faraday's glass	—0.0982 "	1.738 "	Becquerel.	"	—17.7

TABLE 381. — Values of Kerr's Constant.*

Du Bois has shown that the rotation of the major axis of vibration of radiations normally reflected from a magnet is algebraically equal to the normal component of magnetization multiplied into a constant K. He calls this constant K, Kerr's constant for the magnetized substance forming the magnet.

Color of light.	Spectrum line.	Wave-length in cms. $\times 10^6$	Kerr's constant in minutes per c. g. s. unit of magnetization. Cobalt.	Nickel.	Iron.	Magnetite.
Red	Li α	67.7	—0.0208	—0.0173	—0.0154	+0.0096
Red	—	62.0	—0.0198	—0.0160	—0.0138	+0.0120
Yellow	D	58.9	—0.0193	—0.0154	—0.0130	+0.0133
Green	*b*	51.7	—0.0179	—0.0159	—0.0111	+0.0072
Blue	F	48.6	—0.0180	—0.0163	—0.0101	+0.0026
Violet	G	43.1	—0.0182	—0.0175	—0.0089	-

* H. E. J. G. Du Bois, "Phil. Mag." vol. 29.

TABLE 382. — Dispersion of Kerr Effect.

Wave-length.	0.5μ	1.0μ	1.5μ	2.0μ	2.5μ
Steel	—11′.	—16′.	—14′.	—11′.	—9′.0
Cobalt	— 9.5	—11.5	— 9.5	—11.	—6.5
Nickel	— 5.5	— 4.0	0	+1.75	+3.0

Field Intensity = 10,000 C. G. S. units. (Intensity of Magnetization = about 800 in steel, 700 to 800 in cobalt, about 400 in nickel). Ingersoll, Phil. Mag. 11, p. 41, 1906.

TABLE 383. — Dispersion of Kerr Effect.

Mirror.	Field (C. G. S.)	.41μ	.44μ	.48μ	.52μ	.56μ	.60μ	.64μ	.66μ
Iron	21,500	—.25	—.26	—.28	—.31	—.36	—.42	—.44	—.45
Cobalt	20,000	—.36	—.35	—.34	—.35	—.35	—.35	—.35	—.36
Nickel	19,000	—.16	—.15	—.13	—.13	—.14	—.14	—.14	—.14
Steel	19,200	—.27	—.28	—.31	—.35	—.38	—.40	—.44	—.45
Invar	19,800	—.22	—.23	—.24	—.23	—.23	—.22	—.23	—.23
Magnetite	16,400	—.07	—.02	+.04	+.06	+.08	+.06	+.04	+.03

Foote, Phys. Rev. 34, p. 96, 1912.

See also Ingersoll, Phys. Rev. 35, p. 312, 1912, for "The Kerr Rotation for Transverse Magnetic Fields," and Snow, l. c. 2, p. 29, 1913, "Magneto-optical Parameters of Iron and Nickel."

TABLE 384.

MAGNETIC SUSCEPTIBILITY.

If $\mathfrak{I}$ is the intensity of magnetization produced in a substance by a field strength $\mathfrak{H}$, then the magnetic susceptibility $H = \mathfrak{I}/\mathfrak{H}$. This is generally referred to the unit mass; italicized figures refer to the unit volume. The susceptibility depends greatly upon the purity of the substance, especially its freedom from iron. The mass susceptibility of a solution containing p per cent by weight of a water-free substance is, if H_0 is the susceptibility of water, $(p/100)\,H + (1 - p/100)\,H_0$.

Substance.	Susceptibility.	Temp. C.	Remarks	Substance.	Susceptibility.	Temp. C.	Remarks
Ag	—0.19	18°		K_2CO_3	—0.50	20°	Sol'n
AgCl	—0.28			Li	+0.38		
Air, 1 Atm.	*+0.024*	15		Mb	+0.04	18	
Al	+0.65	18		Mg	+0.55	18	
$Al_2K_2(SO_4)_4 24H_2O$	*—1.0*		Crys.	$MgSO_4$	—0.40		
A, 1 Atm	*—0.10*	0		Mn	+11.	18	
As	—0.3	18		$MnCl_2$	+122.	18	Sol'n
Au	—0.15	18		$MnSO_4$	+100.	18	"
B	—0.71	18		N_2, 1 Atm.	*0.001*	16	
$BaCl_2$	—0.36	20		NH_3	—1.1		
Be	+0.79	15	Powd.	Na	+0.51	18	
Bi	—1.4	18		NaCl	—0.50	20	
Br	—0.38	18		$NaCO_3$	—0.19	17	Powd.
C, arc-carbon	—2.0	18		$NaCO_3$. 10 H_2O	—0.46	17	"
C, diamond	—0.49	18		Nb	+1.3	18	
CH_4, 1 Atm.	*+0.001*	16		$NiCl_2$	+40.	18	Sol'n
CO_2, 1 Atm.	*+0.002*	16		$NiSO_4$	+30.	20	"
CS_2	*—0.77*	18		O_2, 1 Atm.	+0.120	20	
CaO	—0.27	16	Powd.	Os	+0.04	20	
$CaCl_2$	—0.40	19	"	P, white	—0.90	20	
$CaCO_3$, marble	*—0.7*			P, red	—0.50	20	
Cd	—0.17	18		Pb	—0.12	20	
$CeBr_3$	+6.3	18		$PbCl_3$	—0.25	15	Powd.
Cl_2, 1 Atm.	—0.59	16		Pd	+5.8	18	
$CoCl_2$	+90.	18	Sol'n	$PrCl_3$	+13.	18	Sol'n
$CoBr_2$	+47.	18	"	Pt.	+1.1	18	
CoI_2	+33.	18	"	$PtCl_4$	0.0	22	Sol'n
$CoSO_4$	+57.	19	"	Rh	+1.1	18	
$Co(NO_3)_2$	+57.	18	"	S	—0.48	18	
Cr	+3.7	18		SO_2, 1 Atm.	—0.30	16	
CsCl	—0.28	17	Powd.	Sb	—0.94	18	
Cu	—0.09	18		Se	—0.32	18	
$CuCl_2$	+12.	20	Sol'n	Si	—0.12	18	Crys.
$CuSO_4$	+10.	20	Sol'n	SiO_2, Quartz	—0.44	20	
CuS	+0.16	17	Powd.	—Glass	—0.5±		
$FeCl_3$	+90.	18	Sol'n	Sn	+0.03	20	
$FeCl_2$	+90.	18	"	$SrCl_2$	—0.42	20	Sol'n
$FeSO_4$	+82.	20	"	Ta	+0.93	18	
$Fe_2(NO_3)_6$	+50.	18	"	Te	—0.32	20	
$FeCn_6K_4$	—0.44		Powd.	Th	+0.18	18	
$FeCn_6K_3$	+9.1		"	Ti	+3.1	18	
He, 1 Atm.	*—0.002*	0		Va	+1.5	18	
H_2, 1 Atm.	*0.000*	16		Wo	+0.33	20	
H_2, 40 Atm.	*0.000*	16		Zn	—0.15	18	
H_2O	—0.79	20		$ZnSO_4$	—0.40		
HCl	*—0.80*	20		Zr	—0.45	18	
H_2SO_4	*+0.78*	20		CH_3OH	—0.73		
HNO_3	*—0.70*	20		C_2H_5OH	—0.80		
Hg	—0.19	20		C_3H_7OH	—0.80		
I	—0.4	20		$C_2H_5OC_2H_5$	*—0.60*	20	
In	0.1±	18		$CHCl_3$	—0.58		
Ir	+0.15	18		C_6H_6	—0.78		
K	+0.40	20		Ebonite	*+1.1*		
KCl	—0.50	20		Glycerine	—0.64	22	
KBr	—0.40	20		Sugar	—0.57		
KI	—0.38	20		Paraffin	*—0.58*		
KOH	—0.35	22	Sol'n	Petroleum	—0.91		
K_2SO_4	—0.42	20		Toluene	—0.77		
$KMnO_4$	+2.0			Wood	—0.2–5		
KNO_3	—0.33	20		Xylene	—0.81		

Values are mostly means taken of values given in Landolt-Börnstein's Physikalisch-chemische Tabellen. See especially Honda, Annalen der Physik (4), 32, 1910.

TABLE 385.—Variation of Resistance of Bismuth, with Temperature, in a Transverse Magnetic Field.

H	Proportional Values of Resistance.								
	−192°	−135°	−100°	−37°	0°	+18°	+60°	+100°	+183°
0	0.40	0.60	0.70	0.88	1.00	1.08	1.25	1.42	1.79
2000	1.16	0.87	0.86	0.96	1.08	1.11	1.26	1.43	1.80
4000	2.32	1.35	1.20	1.10	1.18	1.21	1.31	1.46	1.82
6000	4.00	2.06	1.60	1.29	1.30	1.32	1.39	1.51	1.85
8000	5.90	2.88	2.00	1.50	1.43	1.42	1.46	1.57	1.87
10000	8.60	3.80	2.43	1.72	1.57	1.54	1.54	1.62	1.89
12000	10.8	4.76	2.93	1.94	1.71	1.67	1.62	1.67	1.92
14000	12.9	5.82	3.50	2.16	1.87	1.80	1.70	1.73	1.94
16000	15.2	6.95	4.11	2.38	2.02	1.93	1.79	1.80	1.96
18000	17.5	8.15	4.76	2.60	2.18	2.06	1.88	1.87	1.99
20000	19.8	9.50	5.40	2.81	2.33	2.20	1.97	1.95	2.03
25000	25.5	13.3	7.30	3.50	2.73	2.52	2.22	2.10	2.09
30000	30.7	18.2	9.8	4.20	3.17	2.86	2.46	2.28	2.17
35000	35.5	20.35	12.2	4.95	3.62	3.25	2.69	2.45	2.25

TABLE 386.—Increase of Resistance of Nickel due to a Transverse Magnetic Field, expressed as % of Resistance at 0° and H=0.

H	−190°	−75°	0°	+18°	+100°	+182°
0	+0	0	0	0	0	0
1000	+0.20	+0.23	+0.07	+0.07	+0.96	+0.04
2000	+0.17	+0.16	+0.03	+0.03	+0.72	−0.07
3000	0.00	−0.05	−0.34	−0.36	−0.14	−0.60
4000	−0.17	−0.15	−0.60	−0.72	−0.70	−1.15
6000	−0.19	−0.20	−0.70	−0.83	−1.02	−1.53
8000	−0.19	−0.23	−0.76	−0.90	−1.15	−1.66
10000	−0.18	−0.27	−0.82	−0.95	−1.23	−1.76
12000	−0.18	−0.30	−0.87	−1.00	−1.30	−1.85
14000	−0.18	−0.32	−0.91	−1.04	−1.37	−1.95
16000	−0.17	−0.35	−0.94	−1.09	−1.44	−2.05
18000	−0.17	−0.38	−0.98	−1.13	−1.51	−2.15
20000	−0.16	−0.41	−1.03	−1.17	−1.59	−2.25
25000	−0.14	−0.49	−1.12	−1.29	−1.76	−2.50
30000	−0.12	−0.56	−1.22	−1.40	−1.95	−2.73
35000	−0.10	−0.63	−1.32	−1.50	−2.13	−2.98

F. C. Blake, Ann. der Physik, 28, p. 449; 1909.

TABLE 387.—Change of Resistance of Various Metals in a Transverse Magnetic Field. Room Temperature.

Metal.	Field Strength in Gausses.	Per cent Increase.	Authority.
Nickel	10000	−1.2	Williams, Phil. Mag. 9, 1905.
"	"	−1.4	Barlow, Pr. Roy. Soc. 71, 1903.
"	6000	−1.0	Dagostino, Atti Ac. Linc. 17, 1908.
"	10000	−1.4	Grummach, Ann. der Phys. 22, 1906.
Cobalt	"	−0.53	"
Cadmium	"	+0.03	"
Zinc	"	+0.01	"
Copper	"	+0.004	"
Silver	"	+0.004	"
Gold	"	+0.003	"
Tin	"	+0.002	"
Palladium	"	+0.001	"
Platinum	"	+0.0005	"
Lead	"	+0.0004	"
Tantalum	"	+0.0003	"
Magnesium	6000	+0.01	Dagostino, *l. c.*
Manganin	"	+0.01	"
Tellurium	?	+0.02 to 0.34	Goldhammer, Wied Ann. 31, 1887.
Antimony	?	+0.02 to 0.16	"
Iron	Different specimens show very diverse results, usually an increase in weak fields, a decrease in strong.		Grummach, *l. c.* Barlow, *l. c.* Williams, *l. c.*
Nickel steel	Alloys behave similarly to iron.		Williams, *l. c.*

TABLE 388.—Transverse Galvanomagnetic and Thermomagnetic Effects.

Effects are considered positive when, the magnetic field being directed away from the observer, and the primary current of heat or electricity directed from left to right, the upper edge of the specimen has the higher potential or higher temperature.

E = difference of potential produced; T = difference of temperature produced; I = primary current; $\frac{dt}{dx}$ = primary temperature gradient; B = breadth, and D = thickness, of specimen; H = intensity of field. C. G. S. units.

Hall effect (Galvanomagnetic difference of Potential), $E = R\frac{HI}{D}$

Ettingshausen effect (" " " Temperature), $T = P\frac{HI}{D}$

Nernst effect (Thermomagnetic " " Potential), $E = QHB\frac{dt}{dx}$

Leduc effect (" " " Temperature), $T = SHB\frac{dt}{dx}$

Substance.	Values of R.	$P \times 10^6$.	$Q \times 10^6$.	$S \times 10^6$.
Tellurium	+400 to 800	+200	+360000	+400
Antimony	+ 0.9 " 0.22	+2	+9000 to 18000	+200
Steel	+.012 " 0.033	—0.07	—700 " 1700	+69
Heusler alloy	+.010 " 0.026		+1600 " 7000	
Iron	+.007 " 0.011	—0.06	—1000 " 1500	+39
Cobalt	+.0016 " 0.0046	+0.01	+1800 " 2240	+13
Zinc	–	–	—54 " 240	+13
Cadmium	+.00055			
Iridium	+.00040	–	up to —5.0	+5
Lead	+.00009	–	—5.0 (?)	
Tin	—.00003	–	—4.0 (?)	
Platinum	—.0002	–	–	—2
Copper	—.00052	–	—90 to 270	—18
German silver	—.00054			
Gold	—.00057 to .00071			
Constantine	—.0009			
Manganese	—.00093			
Palladium	—.0007 to .0012	–	+50 to 130	—3
Silver	—.0008 " .0015	–	—46 " 430	—41
Sodium	—.0023			
Magnesium	—.00094 to .0035			
Aluminum	—.00036 " .0037			
Nickel	—.0045 " .024	+0.04 to 0.19	+2000 " 9000	—45
Carbon	—.017	+5.	+100	
Bismuth	— up to 16.	+3 to 40	+ up to 132000	—200

TABLE 389.—Variation of Hall Constant with the Temperature.

Bismuth.[1]						Antimony.[2]				
H	—182°	—90°	—23°	+11.5°	+100°	H	—186°	—79°	+21.5°	+58°
1000	62.2	28.0	17.0	13.3	7.28	1750	0.263	0.249	0.217	
2000	55.0	25.0	16.0	12.7	7.17	3960	0.252	0.243	0.211	
3000	49.7	22.9	15.1	12.1	7.06	6160	0.245	02.35	0.209	0.203
4000	45.8	21.5	14.3	11.5	6.95					
5000	42.6	20.2	13.6	11.0	6.84					
6000	40.1	18.9	12.9	10.6	6.72					

Bismuth.[3]									
H	+14.5°	+104°	125°	189°	212°	239°	259°	269°	270°
890	5.28	2.57	2.12	1.42	1.24	1.11	0.97	0.83	0.77*

[1] Barlow, Ann. der Phys. 12, 1903.
[2] Everdingen, Comm. Phys. Lab. Leiden, 58.
[3] Traubenberg, Ann. der Phys. 17, 1905.
* Melting-point.

Both tables taken from Jahn, Jahrbuch der Radioactivität und Electronik, 5, p. 166; 1908, who has collected data of all observers and gives extensive bibliography.

RÖNTGEN (X-RAYS) RAYS.

Röntgen rays are produced whenever an electric discharge passes through a highly exhausted tube. The disturbance is propagated in straight lines probably with the velocity of light, affects photographic plates, excites phosphorescence, ionizes gases and suffers neither deviation by magnetic forces nor measurable refraction in passing through media of different densities. With extreme exhaustion in the tube they have an appreciable effect after passing through several millimeters of brass or iron. The quality by which it is best to classify the rays is their hardness which is the greater the greater the exhaustion. It is conveniently measured by the amount of absorption which they suffer in passing through a layer of aluminum or tin foil of standard thickness. The number of ions which the rays produce in 1 sec. in passing through 1 cu. cm. of a gas depends upon its nature and pressure. The absorption of any substance is equal to the sum of the absorption of the individual molecules and the absorption due to any molecule is independent of the nature of the chemical compound of which it forms a part, of its physical state, and probably of its temperature.

TABLE 390. — Ionization due to Röntgen Rays in Various Gases.

Gas.	Relative ionization.		Density.
	Soft rays, Strutt.	Hard rays, Eve.	
Hydrogen	.11	.42	0.069
Air	1.00	1.00	1.00
Oxygen	1.39	—	1.11
Carbon dioxide	1.60	—	1.53
Cyanogen	1.05	—	1.86
Sulphur dioxide	7.97	2.3	2.19
Chloroform	31.9	4.6	4.32
Methyl iodide	72.0	13.5	5.05
Carbon tetrachloride	45.3	4.9	5.31
Hydrogen sulphide	—	.9	1.18

Strutt, Proc. Roy. Soc. 72, p. 209, 1903; Eve, Phil. Mag. 8, p. 610, 1904.

When Röntgen rays pass through matter they produce secondary Röntgen rays as well as cathodic rays. The former are of two types: the first is like the original rays and may be regarded as scattered primary rays; the second type varies with the nature of the material struck and is independent of the primary rays. If the atomic weight of the material struck is less than that of Calcium then the first type alone is present. The higher the atomic weight of the material struck the more penetrating is the secondary radiation given out. This is shown in the following table where λ is the reciprocal of the distance (cm.) in Al. through which the rays must pass in order that their intensity is reduced to 1/2.7 of its original intensity.

TABLE 391. — Röntgen Secondary Rays.

Element.	Cr.	Fe.	Co.	Ni.	Cu.	Zn.	As.	Se.	Sr.	Ag.	Sn.
Atomic weight	52.	55.8	59.0	58.7	63.6	65.4	75.0	79.2	87.6	108.	119.
λ	367.	239.	193.	160.	129.	106.	61.	51.	35.2	6.75	4.33

The secondary cathodic rays seem to be independent of the material struck and of the intensity of the original rays. The velocity of these secondary rays depends upon the hardness of the original rays. The following table gives the thickness in cm. of the gas at 760 mm., 0° C. necessary to reduce the energy of the cathodic rays to one half (t) as well as λ as above defined.

TABLE 392. — Röntgen Secondary Cathodic Rays.

Element.	t		λ	
	Air.	Hydrogen.	Air.	Hydrogen
Fe	.0080	.041	87.2	17.0
Cu	.0135	.073	51.9	9.5
Zn	.0164	.091	42.7	7.7
As	.0255		27.4	
Sn	.176	1.37	3.97	.51

Beatty, Phil. Mag. 20, p. 320, 1910.

TABLES 393, 394.

RÖNTGEN (X-RAYS) RAYS.

TABLE 393. — Mean Absorption Coefficients, $\frac{\lambda}{d}$.

If I_0 be the intensity of a parallel beam of homogeneous radiation incident normally on a plate of absorbing material of thickness t, then $I = I_0 e^{-\lambda x}$ gives the intensity I at the depth x. Because of the greater homogeneity of the secondary X-rays they were used in the determination of the following coefficients. The coefficients λ have been divided by the density d.

Radiator.	Absorber.										
	C.	Mg.	Al.	Fe.	Ni.	Cu.	Zn.	Ag.	Sn.	Pt.	Au.
Cr.	15.3	126.	136.	104.	129.	143.	170.	580.	714.	(517.)	(507.)
Fe.	10.1	80.	88.	66.	84.	95.	112.	381.	472.	340.	367.
Co.	8.0	64.	72.	67.	67.	75.	92.	314.	392.	281.	306.
Ni.	6.6	52.	59.	314.	56.	62.	74.	262.	328.	236.	253.
Cu.	5.2	41.	48.	268.	63.	53.	61.	214.	272.	194.	210.
Zn.	4.3	35.	39.	221.	265.	56.	50.	175.	225.	162.	178.
As.	2.5	19.	22.	134.	166.	176.	204.	105.	132.	106.	106.
Se.	2.0	16.	19.	116.	141.	150.	175.	88.	112.	93.	100.
Ag.	.4	2.2	2.5	17.	23.	24.	27.	13.	16.	56.	61.

Barkla, Sadla, Phil. Mag. 17, p. 739, 1909.

TABLE 394. — X-Ray Spectra and Atomic Numbers.

Kaye has shown that an element excited by sufficiently rapid cathode rays emits characteristic Röntgen radiations. These have been analyzed and the wave-lengths obtained by Moseley (Phil. Mag. 27, p. 703, 1914) using a crystal of potassium ferrocyanide as a grating. The "K" series of elements shows 2 lines, α and β, the "L" series several. The wave-lengths of the α and β lines of each series are given in the following table. $Q_K = (v/\frac{3}{4} v_0)^{\frac{1}{2}}$; $Q_L = (v/\frac{5}{36} v_0)^{\frac{1}{2}}$ where v is the frequency of the α line and v_0 the fundamental Rydberg frequency. The atomic number for the K series $= Q_K + 1$; for the L series $= Q_L + 7.4$ approximately. $v_0 = 3.29 \times 10^{15}$.

Element.	α line λx10⁸cm.	Q_K	Atomic Number N	β line λx10⁸cm.	Element.	α line λx10⁸cm.	Q_L	Atomic Number N	β line λx10⁸cm.
Al	8.364	12.0	13	7.912	Zr	6.091	32.8	40	
Si	7.142	13.0	14	6.729	Cb	5.749	33.8	41	5.507
Cl	4.750	16.0	17		Mo	5.423	34.8	42	5.187
K	3.759	18.0	19	3.463	Ru	4.861	36.7	44	4.660
Ca	3.368	19.0	20	3.094	Rh	4.622	37.7	45	
Ti	2.758	21.0	22	2.524	Pd	4.385	38.7	46	4.168
V	2.519	22.0	23	2.297	Ag	4.170	39.6	47	
Cr	2.301	23.0	24	2.093	Sn	3.619	42.6	50	
Mn	2.111	24.0	25	1.818	Sb	3.458	43.6	51	3.245
Fe	1.946	25.0	26	1.765	La	2.676	49.5	57	2.471
Co	1.798	26.0	27	1.629	Ce	2.567	50.6	58	2.360
Ni	1.662	27.0	28	1.506	Pr	(2.471)	51.5	59	2.265
Cu	1.549	28.0	29	1.402	Nd	2.382	52.5	60	2.175
Zn	1.445	29.0	30	1.306	Sa	2.208	54.5	62	2.008
Yt	0.838	38.1	39		Eu	2.130	55.5	63	1.925
Zr	0.794	39.1	40		Gd	2.057	56.5	64	1.853
Cb	0.750	40.2	41		Ho	1.914	58.6	66	1.711
Mo	0.721	41.2	42		Er	1.790	60.6	68	1.591
Ru	0.638	43.6	44		Ta	1.525	65.6	73	1.330
Pd	0.584	45.6	46		W	1.486	66.5	74	
Ag	0.560	46.6	47		Os	1.397	68.5	76	1.201
					Ir	1.354	69.6	77	1.155
					Pt	1.316	70.6	78	1.121
					Au	1.287	71.4	79	1.092

Moseley's summary condensed is as follows: Every element from Al to Au is characterized by an integer N which determines its X-ray spectrum; N is identified with the number of positive units of electricity in its atomic nucleus. The order of these atomic numbers (N) is that of the atomic weights except where the latter disagrees with the order of the chemical properties. Known elements correspond with all the numbers between 13 and 79 except 3. There are here 3 possible elements still undiscovered. The frequency of any line in the X-ray spectrum is approximately proportional to A $(N-b)^2$, where A and b are constants. All X-ray spectra of each series are similar in structure differing only in wave-lengths.

Radioactivity is a property of certain elements of high atomic weight. It is an additive property of the atom, dependent only on it and not on the chemical compound formed nor affected by physical conditions controlling ordinary reactions, viz: temperature, whether solid or liquid or gaseous, etc.

With the exception of actinium, radioactive bodies emit α, β, or γ rays. α rays are easily absorbed by thin metal foil or a few cms. of air and are positively charged atoms of helium emitted with about 1/15 the velocity of light. They are deflected but very slightly by intense electric or magnetic fields. The β rays are on the average more penetrating, are negatively charged particles projected with nearly the velocity of light, easily deflected by electric or magnetic fields and identical in type with the cathode rays of a vacuum tube. The γ rays are extremely penetrating and non-deviable, analogous in many respects to the very penetrating Röntgen rays. These rays produce ionization of gases, act on the photographic plate, excite phosphorescence, produce certain chemical reactions such as the formation of ozone or the decomposition of water. All radioactive compounds are luminous even at the temperature of liquid air.

Table 398 is based very greatly on Rutherford's Radioactive Substances and their radiations (Oct. 1912). To this and to Landolt-Börnstein Physikalisch-chemische Tabellen the reader is referred for references. In the three radioactive series each successive product (except Ur. Y, and Ra. C_2) results from the transformation of the preceding product and in turn produces the following. When the change is accompanied by the ejection of an α particle (helium, atomic weight = 4.0) the atomic weight decreases by 4. The italicized atomic weights are thus computed. Each product with its radiation decays by an exponential law; the product and its radiation consequently depend on the same law. $I = I_0e^{-\lambda t}$ where I_0 = radioactivity when t = O, I that at the time t, and λ the transformation constant. Radioactive equilibrium of a body with its products exists when that body is of such long period that its radiation may be considered constant and the decay and growth of its products are balanced.

International radium standard: As many radioactivity measures depend upon the purity of the radium used, in 1912 a committee appointed by the Congress of Radioactivity and Electricity, Brussels, 1910, compared a standard of 21.99 mg. of pure Ra. chloride sealed in a thin glass tube and prepared by Mme. Curie with similar standards by Hönigschmid and belonging to The Academy of Sciences of Vienna. The comparison showed an agreement of 1 in 300. Mme. Curie's standard was accepted and is preserved in the Bureau international des poids et mesures at Sèvres, near Paris. Arrangements have been made for the preparation of duplicate standards for governments requiring them.

TABLE 395.—Relative Phosphorescence Excited by Radium.

(Becquerel, C. R. 129, p. 912, 1899.)

Without screen,	Hexagonal zinc blende	13.36	With screen	.04
" "	Pt. cyanide of barium	1.99	" "	.05
" "	Diamond	1.14	" "	.01
" "	Double sulphate Ur and K	1.00	" "	.31
" "	Calcium fluoride	.30	" "	.02

The screen of black paper absorbed most of the α rays to which the phosphorescence was greatly due. For the last column the intensity without screen was taken as unity. The γ rays have very little effect.

TABLE 396.—The Production of α Particles (Helium).

(Geiger and Rutherford, Philosophical Magazine, 20, p. 691, 1910.)

Radioactive substance (1 gram.)	α particles per sec.	Helium per year.
Uranium	2.37×10^4	2.75×10^{-5} cu. mm.
Uranium in equilibrium with products	9.7×10^4	11.0×10^{-5} " "
Thorium " " " "	2.7×10^4	3.1×10^{-5} " "
Radium	3.4×10^{10}	39 " "
Radium in equilibrium with products	13.6×10^{10}	158 " "

TABLE 397.—Heating Effect of Radium and its Emanation.

(Rutherford and Robinson, Philosophical Magazine, 25, p. 312, 1913.)

	Heating effect in gram-calories per hour per gram radium.			
	α rays.	β rays.	γ rays.	Total.
Radium	25.1			25.1
Emanation	28.6		–	28.6
Radium A	30.5	–	–	30.5
Radium B + C	39.4	4.7	6.4	50.5
Totals	123.6	4.7	6.4	134.7

Other determinations: Hess, Wien. Ber. 121, p. 1, 1912, Radium (alone) 25.2 cal. per hour per gram. Meyer and Hess, Wien. Ber. 121, p. 603, 1912, Radium in equilibrium, 132.3 gram. cal. per hour per gram. See also, Callendar, Phys. Soc. Proceed. 23, p. 1, 1910; Schweidler and Hess, Ion. 1, p. 161, 1909; Ångström, Phys. ZS. 6, 685, 1905, etc.

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$P = 1/2$ period = time when body is one-half transformed. λ = transformation constant (see previous page). The initial velocity of the α particle is deduced from the formula of Geiger $V^3 = aR$ where R = range and assuming the velocity for RaC of range 7.06 cm. at 20° is 2.06×10^9 cm. per sec., i.e. $v = 1.077 r^{1/3}$.

	Atomic Weights.	½ Period P	Transformation Constants. $\lambda = \frac{.6931}{P}$	Rays.	α rays. Range. 760mm, 15° C.	α rays. Initial Velocity.	α rays. Kinetic Energy	α rays. Whole no. of ions produced.
					c.m.	c.m. per s.	Ergs.	By an α particle.
URANIUM-RADIUM GROUP.								
Uranium 1	238.5	5×10^6 y	1.4×10^{-10} y	α	2.50	1.45×10^9	$.65\times10^{-5}$	1.26×10^5
Uranium 2	*234.5*	10^6 yrs	7×10^{-7} y	α	2.90	1.53 "	.72 "	1.37 "
Uranium X	*230.5*	24.6 d	.0282 d	$\beta+\gamma$				
Ur. Y	*230.5 ?*	1.5 d	.46 d	β				
Ionium	*230.5*	2×10^5 yr ?	3.5×10^{-6} y	α	3.00	1.56 "	.75 "	1.40 "
Radium	226.4	2000 y	.000346 y	$\alpha+\beta$	3.30	1.61 "	.79 "	1.50 "
Ra Emanation	*222*	3.85 d	.180 d	α	4.16	1.73 "	.92 "	1.74 "
Radium A	*218*	3.0 m	.231 m	α	4.75	1.82 "	1.01 "	1.88 "
Radium B	*214*	26.8 m	.0258 m	$\beta+\gamma$				
Radium C	*214*	19.5 m	.0355 m	$\alpha+\beta+\gamma$	6.94	2.06 "	1.31 "	2.37 "
Ra C_2	*210 ?*	1.4 m	.495 m	β				
Ra O, radio-lead	*210*	16.5 y	.042 y	slow β				
Ra E.	*210*	5.0 d	.139 d	$\beta+\gamma$				
Ra F. Polonium	*210*	136 d	.00510 d	α	3.77	1.68 "	.87 "	1.63 "
ACTINIUM GROUP.								
Actinium	*A*	?		none				
Radio-Act.	*A*	19.5 d	.0355 d	$\alpha+\beta$	4.80	1.83×10^9	1.02×10^{-5}	1.89×10^5
Actinium X	*A—4*	10.2 d	.068 d	α	4.40	1.76 "	.94 "	1.79 "
Act. Emanation	*A—8*	3.9 s	.178 s	α	5.70	1.94 "	1.15 "	2.10 "
Actinium A	*A—12*	.002 s	350 s	α	6.50	2.02 "	1.25 "	2.27 "
Actinium B	*A—16*	36 m	.0193 m	slow β				
Actinium C	*A—16*	2.1 m	.33 m	α	5.40	1.89 "	1.10 "	2.02 "
Actinium D	*A—20*	4.7 m	.147 m	$\beta+\gamma$				
THORIUM GROUP.								
Thorium	232	1.3×10^{10} y	5.3×10^{-11}	α	2.72	1.50×10^9	$.69\times10^{-5}$	1.32×10^5
Mesothorium 1	*228*	5.5 y	.126 yr	none				
Mesothorium 2	*228*	6.2 hr	.112 h	$\beta+\gamma$				
Radiothorium	*228*	2 yrs	.347 y	α	3.87	1.70 "	.89 "	1.66 "
Thorium X	*224*	3.65 d	.190 d	$\alpha+\beta$	5.7	1.94 "	1.15 "	2.1 "
Th. Emanation	*220*	54 sec	.0128 s	α	5.5	1.90 "	1.10 "	2.0 "
Thorium A	*216*	0.14 sec	4.95 s	α	5.9	1.97 "	1.19 "	2.2
Thorium B	*212*	10.6 h	.0654 h	$\beta+\gamma$				
Thorium C_1	*212*	60 m	.0118 m	$\alpha+\beta$	5.0	1.85 "	1.05 "	1.9 "
Thorium C_2	*212*	very short	–	α	8.6	2.22 "	1.53 "	2.9 "
Th. D	*208*	3.1 m	.224 m	$\beta+\gamma$				
Potassium	39.1	?	?	β				
Rubidium	85.5	?	?	β				

μ = coefficient of absorption for β rays in terms of cms. of aluminum, μ_1, of the γ rays in cms. of lead so that if J_0 is the incident intensity, J that after passage through d cms., $J = J_0 e^{-d\mu}$.

	β rays.		γ rays.	
	Absorption Coefficient = μ	Velocity Light = 1	Absorption Co-ef. = μ_1	Remarks.
	c.m.$^{-1}$		c.m.$^{-1}$	
URANIUM-RADIUM GROUP.				
Ur 1	—	—	—	1 gram U emits 2.37×10^4 α particles per sec.
Ur 2	—	—	—	Not separable from Ur 1.
Ur X	15, 510	Wide range	.72	β rays show no groups of definite velocities. Chemically allied to Th.
Ur Y	—	—	—	Probably branch product. Exists in small quantity.
Io	—	—	—	Chemically properties of and non-separable from Thorium.
Ra	312	.52, .65	—	Chemically properties of Ba. 1 gr. emits per sec. in equilib. 13.6×10^{10} α particles.
Ra Em	—	—	—	Inert gas, density 111 H, boils —65° C, density solid 5–6, condenses low pressure —150° C.
Ra A	—	—	—	Like solid, has + charge, volatile in H, 400°, in O about 550°.
Ra B	13, 80, 890	.36 to .74	4 to 6	Volatile about 400° C. in H. Separated pure by recoil from Ra A.
Ra C	13, 53	.80 to .98	.50	Volatile in H about 430°, in O about 1000°.
Ra C_2	13	—	—	Probably branch product. Separated by recoil from Ra C.
Ra D	.33, .39	.33, .39	—	Separated with Pb. not yet separable from it. Volatile below 1000°.
Ra E	43	Wide range	Easy abs.	
Ra F	—	—	—	Separated with Bi. Probably changes to Pb. Volatile about 1000°.
ACTINIUM GROUP.				
Act	—	—	—	Probably branch product Ur. series. Chemically allied to Lanthanum.
Rad. Act	140	—	—	
Act X	—	—	—	Chemical properties analogous to Ra.
Ac. Em.	—	—	—	Inert gas, condenses between —120° and —150°.
Act A	—	—	—	Analogous to Ra A. Volatile above 400°.
Act B	Very soft	—	—	" " Ra B. " " 700°.
Act C	—	—	—	" " Ra C.
Act D	28.5	—	.217 (Al)	(Obtained by recoil).
THORIUM GROUP.				
Th.	—	—	—	Volatile in electric arc. Colorless salts not spontaneously phosphorescent.
Mes. Th. 1	—	.37 to .66	—	Chemical property analogous to Ra from which non-separable.
Mes. Th. 2	20 to 38.5	—	.53	
Rad. Th.	—	—	—	Chemically allied to Th., non-separable from it.
Th. X	About 330	.47 .51	—	Chemically analogous to Ra.
Th. Em.	—	—	—	Inert gas, condenses at low pressure between —120° and —150°.
Th. A	—	—	—	+ charged, collected on — electrode.
Th. B	110.	.63 .72	—	Chemically analogous to Ra B. Volatile above 630° C.
Th. C_1	15.6	—	Weak	Chemically analogous to Ra C. Volatile above 730°.
Th. C_2	—	—	—	Th.C_2 and Th.D are probably respectively β and α ray products from Th.C_1.
Th. D	24.8	.3, .4, .93–5	.46	Got by recoil from Th.C. Probably transforms to Bi.
K	38, 102	—	—	Activity = 1/1000 of Ur.
Rb.	380, 1020	—	—	" = 1/500 of Ur.

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TABLE 399.—Stopping Powers of Various Substances for α Rays.

s, the stopping power of a substance for the α rays is approximately proportional to the square root of the atomic weight, w.

Substance	H_2	Air	O_2	C_2H_2	C_2H_4	Al	N_2O	CO_2	CH_3Br	CS_2	Fe
s . . .	.24	1.0	1.05	1.11	1.35	1.45	1.46	1.47	2.09	2.18	2.26
$\sqrt{w}$ . . .	.26	1.0	1.05	1.17	1.44	1.37	1.52	1.51	2.03	1.95	1.97
Substance	Cu	Ni	Ag	Sn	C_6H_6	C_5H_{12}	C_2H_5I	CCl_4	Pt	Au	Pb
s . . .	2.43	2.46	3.17	3.37	3.37	3.59	3.13	4.02	4.16	4.45	4.27
$\sqrt{w}$ . . .	2.10	2.20	2.74	2.88	3.53	3.86	3.06	3.59	3.68	3.70	3.78

Bragg, Philosophical Magazine, 11, p. 617, 1906.

TABLE 400.—Absorption of β Rays by Various Substances.

μ, the coefficient of absorption for β rays is approximately proportional to the density, D. See Table 398 for μ for Al.

Substance .	B	C	Na	Mg	Al	Si	P	S	K	Ca
μ/D . .	4.65	4.4	4.95	5.1	5.26	5.5	6.1	6.6	6.53	6.47
Atomic Wt. .	11	12	23	24.4	27	28	31	32	39	40
Substance . .	Ti	Cr	Fe	Co	Cu	Zn	Ar	Se	Sr	Zr
μ/D	6.2	6.25	6.4	6.48	6.8	6.95	8.2	8.65	8.5	8.3
Atomic Wt. .	48	52	56	59	63.3	65.5	75	79	87.5	90.7
Substance . .	Pd	Ag	Sn	Sb	I	Ba	Pt	Au	Pb	U
μ/D	8.0	8.3	9.46	9.8	10.8	8.8	9.4	9.5	10.8	10.1
Atomic Wt. .	106	108	118	120	126	137	195	197	207	240

For the above data the β rays from Uranium were used.

Crowther, Philosophical Magazine, 12, p. 379, 1906.

TABLE 401.—Absorption of γ Rays by Various Substances.

Substance.	Density.	Radium rays.		Uranium rays.		Th. D. $\mu(cm)^{-1}$	Meso. Th2 $\mu(cm)^{-1}$	Range of thickness cm.
		μ (cm)$^{-1}$	100μ/D	μ(cm)$^{-1}$	100μ/D			
Hg . .	13.59	.642	4.72	.832	6.12			.3 to 3.5
Pb . .	11.40	.495	4.34	.725	6.36	.462	.620	.0 " 7.9
Cu . .	8.81	.351	3.98	.416	4.72	.294	.373	.0 " 7.6
Brass	8.35	.325	3.89	.392	4.70	.271	.355	.0 " 5.86
Fe . .	7.62	.304	3.99	.360	4.72	.250	.316	.0 " 7.6
Sn . .	7.24	.281	3.88	.341	4.70	.236	.305	.0 " 5.5
Zn . .	7.07	.228	3.93	.329	4.65	.233	.300	.0 " 6.0
Slate . .	2.85	.118	4.14	.134	4.69	.096	–	.0 " 9.4
Al . .	2.77	.111	4.06	.130	4.69	.092	.119	.0 " 11.2
Glass .	2.52	.105	4.16	.122	4.84	.089	.113	.0 " 11.3
S . . .	1.79	.078	4.38	.092	5.16	.066	.083	.0 " 11.6
Paraffin .	.86	.042	4.64	.043	5.02	.031	.050	.0 " 11.4

In determining the above values the rays were first passed through one cm. of lead.

Russell and Soddy, Philosophical Magazine, 21, p. 130, 1911.

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TABLE 402. — Total Number of Ions produced by the α, β, and γ Rays.

The total number of ions per second due to the complete absorption in air of the β rays due to 1 gram of radium is 9×10^{14}, to the γ rays, 13×10^{14}.

The total number of ions due to the α rays from 1 gram of radium in equilibrium is 2.56×10^{16}. If it be assumed that the ionization is proportional to the energy of the radiation, then the total energy emitted by radium in equilibrium is divided as follows: 92.1 parts to the α, 3.2 to the β, 47 to the γ rays. (Rutherford, Moseley, Robinson.)

TABLE 403. — Amount of Radium Emanation. Curie.

At the Radiology Congress in Brussels in 1910, it was decided to call the amount of emanation in equilibrium with 1 gram of pure radium one Curie. [More convenient units are the millicurie (10^{-8}Curie) and the microcurie (10^{-6}Curie)]. The rate of production of this emanation is 1.24×10^{-9} cu. cm. per second. The volume in equilibrium is 0.59 cu. mm. (760 cm., 0°C.) assuming the emanation mon-atomic.

The Mache unit is the quantity of Radium emanation without disintegration products which produces a saturation current of 10^{-8} unit in a chamber of large dimensions. 1 curie $= 2.5 \times 10^{9}$ Mache units.

The amount of the radium emanation in the air varies from place to place; the amount per cubic centimeter of air expressed in terms of the number of grams of radium with which it would be in equilibrium varies from 24×10^{-12} to 350×10^{-12}.

TABLE 404. — Vapor Pressure of the Radium Emanation in cms. of Mercury.

(Rutherford and Ramsay, Phil. Mag. 17, p. 723, 1909, Gray and Ramsay, Trans. Chem. Soc. 95, p. 1073, 1909.)

Temperature C°.	−127°	−101°	−65°	−56°	−10°	+17°	+49°	+73°	+100°	+104° (crit)
Vapor Pressure.	0.9	5	76	100	500	1000	2000	3000	4500	4745

TABLE 405. — References to Spectra of Radioactive Substances.

Radium spectrum:	Demarçay, C. R. 131, p. 258, 1900.
Radium emanation spectrum:	Rutherford and Royds, Phil. Mag. 16, p. 313, 1908; Watson, Proc. Roy. Soc. A 83, p. 50, 1909.
Polonium spectrum:	Curie and Debierne, Rad. 7, p. 38, 1910, C. R. 150, p. 386, 1910.

TABLE 406.

MISCELLANEOUS CONSTANTS (ATOMIC, MOLECULAR, ETC.).

Elementary electrical charge, charge on electron, 1/2 charge on α particle,	$e = 4.774 \times 10^{-10}$ e. s. u. (M) $= 1.519 \times 10^{-20}$ e. m. u. $= 1.591 \times 10^{-19}$ coulombs
Mass of an electron,	$m =$ about 6×10^{-28} grams.
Radius of an electron,	$l =$ about 1×10^{-13} cm.
Number of molecules per gram molecule,	$N = 6.06 \times 10^{23}$ gr^{-1} (M)
Number of gas molecules per cc., 760^{mm}, 0°C,	$n = 2.70 \times 10^{19}$ (M)
Kinetic energy of a molecule at 0°C,	$E_0 = 5.62 \times 10^{-14}$ ergs. (M)
Constant of molecular energy, E_0/T,	$\epsilon = 2.06 \times 10^{-16}$ ergs/degrees (M)
Constant of entropy equation (Boltzmann), $= R/N = p_0V_0/TN = (2/3)\ \epsilon$,	$k = 1.37 \times 10^{-16}$ " " (M)
Elementary "Wirkungsquantum,"	$h = 6.62 \times 10^{-27}$ erg. sec. (M)
Mass of hydrogen atom,	$= 1.64 \times 10^{-24}$ gram.
Radius of an atom,	$=$ about 10^{-8} cm.
Gas constant, $R = 22.412/273.1$ for 1 gram molecule of an ideal gas. Pressure in atmospheres, $g = 980.6$, vol. in liters,	$R = .08207$ liter. Atm/grm.

	H_2	He	N_2	O_2	Xe	CO_2	H_2O
Sq. rt. of mean sq. molec. veloc., cm./sec. at 0°C. $\times 10^{-4}$	18.4	13.1	4.93	4.61	2.28	3.92	7.08
Mean free path cm. $\times 10^6$	18.	28.	9.4	9.9	5.6	6.4	7.2
Molecular diameter cm. $\times 10^8$	2.2	2.2	3.3	3.0	3.4	4.2	3.8

(M) Millikan, Phys. Rev. 2, p. 109, 1913. The other values are mostly means.

Table 407.

PERIODIC SYSTEM OF THE ELEMENTS.

0	I	II	III	IV	V	VI	VII	
	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4 Oxides
				RH_4	RH_3	RH_2	RH	– Hydrides
He 4	Li 7	Gl 9	B 11	C 12	N 14	O 16	F 19	– –
Ne 20	Na 23	Mg 24	Al 27	Si 28	P 31	S 32	Cl 35	– –
A 40	K 39	Ca 40	Sc 44	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Ni 59 Co 59
– –	Cu 64	Zn 65	Ga 70	Ge 72	As 75	Se 79	Br 80	– –
Kr 82	Rb 85	Sr 88	Yt 89	Zr 91	Cb 94	Mo 96	– –	Ru 102 Rh 103 Pd 107
– –	Ag 108	Cd 112	In 115	Sn 119	Sb 120	Te 128	I 127	– –
X 128	Cs 133	Ba 137	La 139	Ce 140	–	– –	– –	– –
– –	– –	– –	– –			– –	– –	– –
– –	– –	– –	Yb 173	– –	Ta 181	W 184	– –	Os 191 Ir 193 Pt 195
– –	Au 197	Hg 201	Tl 204	Pb 207	Bi 208	– –	– –	–
– –	– –	Ra 226	– –	Th 232	– –	U 238	–	–

APPENDIX.

DEFINITIONS OF UNITS.

ACTIVITY. Power or rate of doing work; unit, the watt.

AMPERE. Unit of electrical current. The international ampere, "which is one tenth of the unit of current of the C. G. S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and in accordance with accompanying specifications" (*see* pages xxxvi, 261), "deposits silver at the rate of 0.001118 of a gram per second."

The ampere = 1 coulomb per second = 1 volt through 1 ohm = 10^{-1} E. M. U. = 3 × 10^{9} E. S. U.*

Amperes = volts/ohms = watts/volts = $(\text{watts}/\text{ohms})^{\frac{1}{2}}$.

Amperes × volts = amperes^2 × ohms = watts.

ANGSTROM. Unit of wave-length = 10^{-10} meter.

ATMOSPHERE. Unit of pressure.

English normal = 14.7 pounds per sq. in = 29.929 in. = 760.18 mm. Hg. 32° F.

French " = 760 mm. of Hg. 0° C. = 29.922 in. = 14.70 lbs. per sq. in.

BOUGIE DECIMALE. Photometric standard; *see* page 178.

BRITISH THERMAL UNIT. Heat required to raise one pound of water at its temperature of maximum density, 1° F. = 252 gram-calories.

CALORY. Small calory = gram-calory = therm = quantity of heat required to raise one gram of water at its maximum density, one degree Centigrade.

Large calory = kilogram-calory = 1000 small calories = one kilogram of water raised one degree Centigrade at the temperature of maximum density.

For conversion factors *see* page 237.

CANDLE. Photometric standard, *see* page 178.

CARAT. The diamond carat standard in U. S. = 200 milligrams. Old standard = 205.3 milligrams = 3.168 grains.

The gold carat: pure gold is 24 carats; a carat is 1/24 part.

CARCEL. Photometric standard; *see* page 178.

CIRCULAR AREA. The square of the diameter = 1.2733 × true area.

True area = 0.785398 × circular area.

COULOMB. Unit of quantity. The international coulomb is the quantity of electricity transferred by a current of one international ampere in one second. = 10^{-1} E. M. U. = 3 × 10^{9} E. S. U.

Coulombs = (volts-seconds)/ohms = amperes × seconds.

CUBIT = 18 inches.

DAY. Mean solar day. = 1440 minutes = 86400 seconds = 1.0027379 sidereal day.

Sidereal day = 86164.10 mean solar seconds.

DIGIT. 3/4 inch; 1/12 the apparent diameter of the sun or moon.

DIOPTER. Unit of "power" of a lens. The number of diopters = the reciprocal of the focal length in meters.

DYNE. C. G. S. unit of force = that force which acting for one second on one gram produces a velocity of one centimeter per second.

= weight in grams divided by the acceleration of gravity in cm. per sec.

ELECTROCHEMICAL EQUIVALENT is the ratio of the mass in grams deposited in an electrolytic cell by an electrical current to the quantity of electricity.

ENERGY. *See* Erg.

ERG. C. G. S. unit of work and energy = one dyne acting through one centimeter.

For conversion factors *see* page 237.

FARAD. Unit of electrical capacity. The international farad is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity. = 10^{-9} E. M. U. = 9 × 10^{11} E. S. U.

The one-millionth part of a farad (microfarad) is more commonly used.

Farads = coulombs/volts.

* E. M. U. = C. G. S. electromagnetic units. E. S. U. = C. G. S. electrostatic units.

FOOT-POUND. The work which will raise one pound one foot high.
For conversion factors *see* page 237.
FOOT-POUNDALS. The English unit of work = foot-pounds/g.
For conversion factors *see* page 237.
g. The acceleration produced by gravity.
GAUSS. A unit of intensity of magnetic field = 1 E. M. U. = $\frac{1}{9} \times 10^{-10}$ E. S. U.
GRAM. *See* page 6.
GRAM-CENTIMETER. The gravitation unit of work = g. ergs.
GRAM-MOLECULE, = x grams where x = molecular weight of substance.
GRAVITATION CONSTANT = G in formula $G\frac{m_1 m_2}{r_2}$ = 666.07 $\times 10^{-10}$ cm.^{3}/gr. sec.^{2}
For further conversion factors *see* page 237.
HEAT OF THE ELECTRIC CURRENT generated in a metallic circuit without self-induction is proportional to the quantity of electricity which has passed in coulombs multiplied by the fall of potential in volts, or is equal to (coulombs $\times$ volts)/4.181 in small calories.
The heat in small or gram-calories per second = (amperes^2 $\times$ ohms)/4.181 = volts^2/(ohms $\times$ 4.181) = (volts $\times$ amperes)/4.181 = watts/4.181.
HEAT. Absolute zero of heat = −273.13° C, −459.6° Fahrenheit, −218.5° Reaumur.
HEFNER UNIT. Photometric standard; *see* page 178.
HENRY. Unit of induction. It is "the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second." = 10^9 E. M. U. = $\frac{1}{9} \times 10^{-11}$ E. S. U.
HORSE-POWER. The practical unit of power = 33,000 pounds raised one foot per minute. = 550ft. pds. per sec. = 0. 746 kilowatt = 746 watts.
JOULE. Unit of work = 10^7 ergs.
Joules = (volts^2 $\times$ seconds)/ohms = watts $\times$ seconds = amperes^2 $\times$ ohms $\times$ sec.
For conversion factors *see* page 237.
JOULE'S EQUIVALENT. The mechanical equivalent of heat = 4.185 $\times 10^7$ ergs. *See* page 227.
KILODYNE. 1000 dynes. About 1 gram.
LITER. *See* page 6.
LUMEN. Unit of flux of light-candles divided by solid angles.
MEGABAR. Unit of pressure = 0.987 atmospheres.
MEGADYNE. One million dynes. About one kilogram.
METER. *See* page 6.
METER CANDLE. The intensity lumination due to standard candle distant one meter.
MHO. The unit of electrical conductivity. It is the reciprocal of the ohm.
MICRO. A prefix indicating the millionth part.
MICROFARAD. One millionth of a farad, the ordinary measure of electrostatic capacity.
MICRON. (μ) = one millionth of a meter.
MIL. One thousandth of an inch.
MILE. *See* pages 5, 6.
MILE, NAUTICAL or GEOGRAPHICAL = 6080.204 feet.
MILLI-. A prefix denoting the thousandth part.
MONTH. The anomalistic month = time of revolution of the moon from one perigee to another = 27.55460 days.
The nodical month = draconitic month = time of revolution from a node to the same node again = 27.21222 days.
The sidereal month = the time of revolution referred to the stars = 27.32166 days (mean value), but varies by about three hours on account of the eccentricity of the orbit and "perturbations."
The synodic month = the revolution from one new moon to another = 29.5306 days (mean value) = the ordinary month. It varies by about 13 hours.
OHM. Unit of electrical resistance. The international ohm is based upon the ohm equal to 10^9 units of resistance of the C. G. S. system of electromagnetic units, and "is represented by the resistance offered to an unvarying electric current by a column of mercury, at the temperature of melting ice, 14.4521 grams in mass, of a constant cross section and of the length of 106.3 centimeters." = 10^9 E. M. U. = $\frac{1}{9} \times 10^{-11}$ E. S. U.
International ohm = 1.01367 B. A. ohms = 1.06292 Siemens' ohms.
B. A. ohm = 0.98651 international ohms.
Siemens' ohm = 0.94080 international ohms. *See* page 272.
PENTANE CANDLE. Photometric standard. *See* page 178.
PI = π = ratio of the circumference of a circle to the diameter = 3.14159265359.
POUNDAL. The British unit of force. The force which will in one second impart a velocity of one foot per second to a mass of one pound.
RADIAN = 180°/π = 57.29578° = 57° 17′ 45″ = 206625″.
SECOHM. A unit of self-induction = 1 second $\times$ 1 ohm.

THERM = small calory = quantity of heat required to warm one gram of water at its temperature of maximum density one degree Centigrade.

THERMAL UNIT, BRITISH = the quantity of heat required to warm one pound of water at its temperature of maximum density one degree Fahrenheit = 252 gram-calories.

VOLT. The unit of electromotive force (E. M. F.). The international volt is "the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere, and which is represented sufficiently well for practical use by 1000/1434 of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C and prepared in the manner described in the accompanying specification." $= 10^8$ E. M. U. = 1/300 E. S. U. *See* pages xxxiv and 261.

VOLT-AMPERE. Equivalent to Watt/Power factor.

WATT. The unit of electrical power = 10^7 units of power in the C. G. S. system. It is represented sufficiently well for practical use by the work done at the rate of one Joule per second.

Watts = volts × amperes = amperes^2 × ohms = volts^2/ohms (direct current or alternating current with no phase difference).

For conversion factors *see* page 237.

Watts × seconds = Joules.

WEBER. A name formerly given to the coulomb.

YEAR. *See* page 109.

Anomalistic year	= 365 days,	6 hours,	13 minutes,	48 seconds.	
Sidereal "	= 365 "	6 "	9 "	9.314 seconds.	
Ordinary "	= 365 "	5 "	48 "	46 + "	
Tropical "	same as the ordinary year.				

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For the definition of units, see Appendix.

The Riverside Press
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